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Calibration

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Synonyms

Absolute accuracy; Confidence in retrieval; Prospective judgment; Retrospective judgment; Test postdiction; Test prediction

Definition

Calibration is the degree to which a person's perception of performance corresponds with his or her actual performance (Keren 1991). The degree of correspondence is determined by a person's judgment of his or her performance compared against an objectively determined measure of that performance (Hacker et al. 2008). That judgment, which involves self-evaluation, defines calibration as a metacognitive monitoring process. To illustrate, consider the following example. Before taking an exam, a student might estimate how well he or she will perform on the exam, and then estimate after taking the exam how well he or she did perform. If this student predicted that she would score an 85 but actually scored a 90, she is fairly accurate but a bit underconfident. Alternatively, if a student predicts that he will score a 95 and actually scores a 60, he is grossly inaccurate and overconfident. In the former case, the student's perception of performance corresponds well with actual performance, and therefore, she is well calibrated. In the latter case, the student's perception of performance corresponds poorly with actual performance and therefore is poorly calibrated.

Although there are various methods of measuring calibration, all measures of calibration provide a quantitative assessment of the degree of discrepancy between perceived performance and actual performance (Hacker et al. 2008). The various methods can be grouped into two categories: difference scores and calibration curves. Difference scores involve calculating the difference between a person's judged performance and his or her actual performance. Judged performance can entail judgments made on a percentage of likelihood scale or confidence scale; they can be made at a global level, in which a single judgment over multiple items is made or at the item level and averaged over multiple items; and judgments can be made before (predictions or prospective judgments) or after (postdictions or retrospective judgments) performance. Often, the absolute value of the difference between judgment and performance is taken, in which case, values closer to zero indicate greater calibration accuracy, with perfect calibration at zero. If the signed difference is calculated, a bias score is produced. Negative values are interpreted as underconfidence and positive values as overconfidence. In our example, the first student predicted an 85 and scored a 90, which means the difference score would be −5, indicating slight underconfidence; and the second student predicted a 95 and scored a 60, putting the difference at + 35, indicating large overconfidence.

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The other method used for measuring calibration is the calibration curve or graph (Keren 1991). Actual performance is plotted on the y-axis, and judged performance is plotted on the x-axis. Perfect calibration is represented by the 45° line, that is, judgments are exactly equal to performance. Points that fall below the 45° line are interpreted as overconfidence, and points that fall above the line are interpreted as underconfidence. Calibration curves are easily interpreted and provide a graphical means of representing the degree of correspondence between perceptions of performance and actual performance.

In the metacognitive literature, an important distinction is made between calibration and discrimination or resolution (Nelson 1996). Calibration is a measure of absolute accuracy, and discrimination is a measure of relative accuracy. Although both constructs involve metacognitive monitoring, they represent different aspects of metacognitive monitoring and are measured in different ways. Whereas, calibration provides estimates of the degree to which a person's perception of performance corresponds with his or her actual performance, relative accuracy provides estimates of the degree to which a person's judgments can predict the likelihood of correct performance of one item relative to another (Nelson 1996). Calibration provides estimates of overall memory retrieval, and relative accuracy provides estimates of whether a person can discriminate between what is known or not known. Studies that have compared absolute and relative accuracy have found only small correlations between the two, suggesting that the two types of accuracy are tapping different aspects of metacognitive monitoring (e.g., Hacker et al. 2011).

Theoretical Background

Calibration is a metacognitive monitoring process. Monitoring provides information at the metacogntive level about the status of one's knowledge or strategies at a cognitive level (Nelson 1996). Based on this information, metacognitive control can be exerted to regulate one's knowledge or strategies. More specifically, after a person acquires and hopefully retains a specific chunk of knowledge, he or she may evaluate the status of that knowledge in memory, that is, to what degree does the person believe the knowledge has been retained. There may be many contributing variables to that evaluation. People may directly access their memories to evaluate the status of their knowledge, they may make evaluations based on inferences or heuristics about how much they believe they know about a general domain, they may make evaluations based on how self-efficacious they feel about their performance on a particular task, or all of these contributors may come into play. The accuracy of the calibration judgment will be determined by how well all those contributors to the judgment are able to predict performance on a criterion task. In other words, calibration accuracy depends on the extent to which memories are accessed, the inferences or heuristics are made, or the self-efficaciousness felt conform to the knowledge that is tested on the criterion task.

Accurate calibration is an essential component of effective self-regulated learning. In an era of high stakes tests and accountability, the ability to perform well on tests is essential. Students studying for a test need to be accurate in their monitoring of their knowledge retention if they hope to successfully control further study. Students who are overconfident (i.e., a positive bias in calibration judgments) may have a false sense of how well they have mastered the material. They may believe they are prepared when in fact they are at risk for failure. Or students could intentionally inflate their overconfidence during test preparation as a self-handicapping strategy, excusing or attributing their poor performance to external causes (Winne 2004). Underconfidence (i.e., a negative bias in calibration judgments) also can be detrimental to academic performance because students may fail to disengage from studying and misallocate study time if they assume the material is not yet mastered. When students demonstrate strong biases in their calibration judgments, they may not take the remedial steps necessary to improve or carefully evaluate their responses during or after an exam (Hacker et al. 2008). "Learning will be inversely proportional to the degree of calibration bias and proportional to calibration accuracy" (Winne 2004, p. 476).

Important Scientific Research and Open Questions

There are some consistent findings in the literature related to calibration accuracy. Many studies have indicated that calibration accuracy is linked to achievement level (e.g., Bol et al. 2005; Hacker et al. 2000). More specifically, higher-achieving students tend to be more accurate but underconfident when compared to their lower-achieving counterparts who are less accurate and overconfident. Calibration inaccuracy and overconfidence among the lower-achieving students has been linked to theories of self-serving bias, attribution theory, self-handicapping strategies, and ego defense (Bol et al. 2005; Hacker et al. 2008). Lower-achieving students seem to anchor their calibration judgments on optimistic yet inaccurate beliefs about their own abilities rather than prior performance in an effort to protect their sense of self-worth.

Another consistent finding is that predictions are almost always less accurate than postdictions. This phenomenon is known as the testing effect or the upgrading of prediction accuracy (Pressley and Ghatala 1990). Upgrading makes intuitive sense because a person should be better able to judge how he or she performed on a task at the completion of the task due to familiarity and exposure. Consider the context of test-taking. Once students have completed a test, their predictive judgments of performance turn from expectations of what may happen to postdictive judgments of what actually happened. The test itself and students' performance on it provide feedback that informs their postdictions (Hacker et al. 2000).

However, task difficulty also influences calibration accuracy. In fact, the upgrading of prediction accuracy has been reduced when more complex tasks are required. Juslin et al. (2000) have worked with the hard-easy effect in which students tend to be more accurate but underconfident on easy items and less accurate but overconfident on difficult items. This phenomenon is related to achievement level. Lower-achieving students tend to be less accurate and overconfident than their higher-achieving peers on the more difficult items. There is less variability in accuracy on easy items as a function of achievement level.

Attempts to improve calibration accuracy, or to debias calibration judgments, in classroom settings have been met with mixed success (Hacker et al. 2008). Repeated calibration practice, across trials, does not seem to enhance accuracy, particularly among lower-achieving students. Calibration tends to be stable, suggesting that feedback and practice alone are insufficient for improving calibration accuracy. Reflection and instruction on monitoring and calibration were found to be effective, particularly for higher-achieving students. External rewards or incentives were found to enhance postdiction accuracy among lower-achieving students. More recently, group calibration practice and the provision of guidelines have been shown to improve calibration accuracy and achievement among high school students (Bol et al. 2009).

Attempts to further identify consistent patterns of findings across calibration studies are compromised by the lack of common definitions and standard measures. Some researchers refer to calibration as confidence or self-efficacy; whereas, others refer simply to self-monitoring and not necessarily calibration. Variations in how calibration has been measured exacerbate the problem (e.g., local or global judgments, confidence ratings, absolute differences). A common terminology and standard measurement procedures would advance this line of inquiry.

Several other important open questions remain. The first centers on ecological validity or the ability to generalize findings from laboratory-based studies to studies conducted in more naturalistic settings such as classrooms. A closely related issue is population validity or the ability to generalize results beyond college-age students. The vast majority of calibration studies have been conducted with college students, in laboratory settings, and employ inauthentic tasks. Further research on effective interventions is warranted. Studies investigating the effectiveness of interventions for improving calibration accuracy and confirming its link to achievement are needed. Past research has suggested that the effectiveness of interventions may vary depending on prior achievement, implying that interventions might be tailored to better meet the needs of students at risk for failure. Initiating studies on the psychological bases of judgments also will be a productive addition to the literature. What are the significant contributing variables to calibration: Can people directly access memory and accurately judge the status of memories; are inferences based on domain knowledge or self-efficacy responsible; or do people rely on anchoring heuristics? Finally, researchers might further explore how calibration judgments are influenced by social variables. Two avenues for future study include attributional retraining to promote more accurate or realistic metacogntive judgments and calibration practice in group settings.

Cross-References

► Comprehension Monitoring
► Metacognition and Learning
► Metacomprehension
► Self-Efficacy for Self-Regulated Learning
► Self-Regulated Learning
► Self-Regulation and Motivational Strategies

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Calibration of Comprehension

► Comprehension Monitoring

Calibration of Probability Judgments

► Overconfidence

Capacity Limitations of Memory and Learning

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Synonyms

Central bottleneck; Short-term memory; Working memory

Definition

While human capacity for information in the long term is very large, the amount of information that can be actively maintained and manipulated in the short term is quite small. Our ability to take information in, to explicitly hold it in mind, and to mentally manipulate it in the short term is limited. Thus, capacity limitations of memory and learning refer to constraints in our ability to maintain and process information held in the short term that affect long-term understanding and retention.

Theoretical Background

Modern study of memory limitations originated in the early 1950s with the work of George Miller (1956) who suggested that short-term memory has a capacity of 7 ± 2 items. This classic short-term limit is often measured using the forward span, the task of simply recalling a list of items immediately after they are presented. Miller noted that this limit of 7 ± 2 remains constant even across large changes in the amount of information an item represents. For example, while an individual can only recall about seven letters from a list, they also recall about seven words. To explain this property of short-term memory, that the amount of information in short-term memory (seven letters or seven words of letters) depends on the type of information being stored, Miller introduced the idea of *chunks*.

Chunks are the basic unit of short-term memory, composed not of the smallest atom of information, but instead of an interrelated collection of items (such as a word). Because the interrelations between these items are stored in long-term memory (e.g., knowledge about words), they do not take up further space in short-term memory. In fact, because larger chunks take up an identical amount of space in short-term memory, chunks act to extend short-term information capacity. Thus, Miller found that while short-term memory is limited to 7 ± 2 chunks, depending on the content they represent, the chunks themselves can store a huge amount of information.

Though Miller's highly influential work pioneered modern research on the structure of memory, simple short-term capacity lacked sufficient detail to explain more complex tasks, such as learning and problem solving. In an effort to overcome this limitation, Baddeley and Hitch (1974) proposed *working memory*, a model of short-term capacity that focused, in particular, on how memory is applied toward complex processing goals as opposed to recalling simple lists. In the original framework, short-term processing is carried out by a system consisting of three components. The first, active component of this system is the *central executive*. The central executive has no memory capacity itself, but instead manipulates content stored in the other two components of the system – the so-called slave systems. The slave systems, the *phonological loop* and *visuospatial sketchpad*, are limited-capacity passive stores that hold content specific to a particular modality. The phonological loop holds acoustic information, while the visuospatial sketchpad holds visual information. A fourth component has also been added – a multimodal episodic buffer that serves to bind information from the phonological loop, the visuospatial sketchpad, and long-term memory into a unitary episodic representation.

The Baddeley and Hitch model of working memory is valuable because it yields specific predictions about the nature of online processing. In particular, because the phonological loop and visuospatial sketchpad are dissociable stores, learning and performance scenarios that draw on one store are unaffected by demands placed on the second. For example, a spatial task such as mental rotation is relatively unaffected by reciting "the" over and over again (a secondary task known as articulatory suppression). This is because, while both tasks require the temporary maintenance of short-term information, the spatial task relies on the visuospatial sketchpad and articulatory suppression recruits the phonological loop. On the other hand, verbal tasks such as reading are impaired by articulatory suppression because both processes rely on the phonological loop.

Perhaps, the most important contribution of Baddeley and Hitch's working memory model was the explicit pairing of storage with processing via the central executive. Although details of the central executive are left relatively unspecified, its role is to allocate attention (i.e., determine what content is placed in the temporary stores) and mediate the active processing of content stored in the slave systems. These characteristics of the central executive account for basic expectations about memory performance – for example, that short-term stores are not automatically overwritten by new stimuli in the environment and that complex tasks share a common processing resource, regardless of the modality of their content.

Research on the capacity limitations of memory and learning has advanced with particular emphasis on the active processing perspective. One criticism of early short-term memory approaches was that, while individuals differ in their short-term capacity as measured by forward span, these differences are only weakly related to performance on more complex processing tasks. However, measures of capacity that involve both storage and processing, such as Daneman and Carpenter's (1980) *reading span* exhibit highly robust correlations with performance on complex tasks such as reading comprehension and vocabulary learning. Although initially thought to reflect domain-specific language capacities, reading span also correlates with measures of "executive control," such as the ability to filter out irrelevant content, maintain task goals, and inhibit prepotent responses. This has led to the claim that reading span and other complex storage and processing tasks tap into a domain-general *working memory capacity* (Turner and Engle 1989). Differences in working memory capacity relate to performance in a number of complex processing and learning activities such as encoding of new information, memory retrieval, reasoning, rule-based and logic learning, mathematical performance, following directions, and language comprehension.

Important Scientific Research and Open Questions

Because working memory capacity has been identified as a highly robust predictor of complex behavior, a great deal of capacity research is concerned with studying this construct – asking questions about its fundamental structure, its specific role in complex behavior, and about the conditions that may affect its normal operation. One such question is the extent to which working memory capacity represents a stable property of the individual or is malleable based on experience. While there is clear evidence that working memory capacity varies across development, how much of this variation is a function of intellectual experience or is predetermined by neural development is not well established.

One tool for resolving this debate resides in training studies that expose participants to a regimen of demanding working memory tasks. While early results in this literature were criticized for their lack of appropriate controls, recent work has shown evidence of effective capacity training under more rigorous conditions. However, the debate regarding whether or not working memory capacity can be enhanced via training is by no means settled. For instance, evidence from twin studies suggests that the development and capacity of working memory does have a genetic component. While this finding does not preclude the efficacy of training interventions, it does suggest that, in the normal population, biological predispositions also play a role in determining capacity limitations of the individual.

The positive association between working memory capacity and academic performance has become a pervasive finding in the psychology and education literatures. Yet, the full maturation of this resource is completed only after an individual reaches adulthood, long after many critical learning milestones have been surpassed. This has lead to the proposal that working memory capacity might actually impede the acquisition of some linguistic and creativity tasks (Thompson-Schill et al. 2009). Higher levels of working memory related to age or natural variation in adults can actually impede the learning of certain skills that are best acquired without the guidance of explicit rule-based reasoning processes – processes thought to be at the heart of working memory capacity. Thus, while working memory capacity is critical for many learning situations, under certain conditions, increased capacity may not always be a good thing.

One final avenue of research has provided evidence that the capacity of working memory may even vary depending on context. Specifically, scenarios that are highly stressful have been found to disrupt the normal operation of working memory and thus interfere with normal learning and performance. This has been shown in a variety of stressful situations. For example, when a math-anxious individual is placed in a math-related situation, their ability to allocate working memory toward task-related processes is interfered with by their anxiety about the task. This results in worse performance, particularly on those problems and situations that place the most demands on working memory (Ashcraft and Kirk 2001). This negative relationship between anxiety and working memory capacity has been replicated in situations where high-stakes incentives (like a standardized test) or negative stereotypes (e.g., for women, the stereotype that women are bad at math) lead to performance anxiety (see, Beilock 2008 for a review). These scenarios carry important real-world implications for the relationship between situational factors and online capacity limitations in learning and memory.

Cross-References

► Abilities to Learn: Cognitive Abilities
► Cognitive Load Theory
► Individual Differences
► Intelligence, Learning and Neural Plasticity
► Short-Term Memory

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Career Interests

► Stability and Change in Interest Development

Carroll's Model of School Learning

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Synonyms

Conceptual model of school learning

Definition

Carroll's model of school learning specifies the distinctive roles of generalized abilities and task-specific aptitudes in determining the effects of instruction on learning. The degree of learning effectiveness is defined as a function of the time needed for learning and the time actually spent for learning. Both variables, in turn, are dependent on other internal and external variables, such as the learner's general intelligence and the quality of instruction.

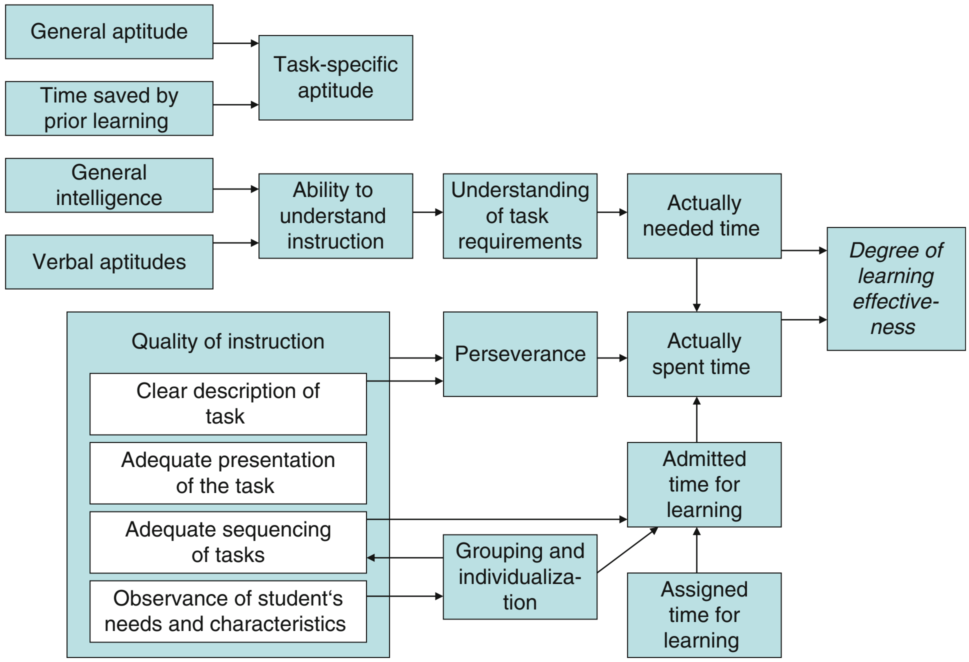
Theoretical Background

In the 1960s, Carroll developed a conceptual model of school learning in which the factor time plays a central role (Carroll 1963). In this model, the achievement of a student or the degree of learning effectiveness is defined as a function of the *actual time needed for learning* and the *time actually spent for learning*. The effect of both variables on the degree of learning effectiveness has been expressed in a functional equation:

$$\text{Degree of learning} = f\left(\frac{\text{Time actually spent for learning}}{\text{Actually spent time for learning}}\right)$$

Both time variables refer only to active learning and are dependent on other variables, such as understanding of the task requirements and the student's aptitude for a particular task. The understanding of task requirements is considered a function of quality of instruction and the student's ability to understand instruction that in turn depends on the student's general intelligence and verbal aptitudes. The individual task-specific aptitude on its part is considered a function of basic aptitudes and the time saved by prior learning. All together, Carroll's model of school learning can be depicted as in Fig. 1.

A central educational perspective in Carroll's model is the concept of *quality of instruction*. He distinguishes between the substance or content of a learning task and its communication which plays the most important role for instructional quality. More specifically, quality of instruction contains a clear description of the learning task, its adequate presentation to the students, as well as an appropriate sequencing of learning tasks and a sufficient observance of the students' characteristics. This distinction allows differentiating between aptitudes and capabilities that are immediately relevant for learning and abilities which are necessary for understanding instruction. In the case that the quality of instruction is high there is no high demand for understanding the instruction. The time actually needed for learning can be referred to task-specific aptitudes. In contrast only students with very good task-specific aptitudes can understand low-level quality instruction



Carroll's Model of School Learning. Fig. 1 Carroll's model of school learning

whereas students with a lack of task-specific aptitudes need more time for learning.

In consequence, Carroll distinguishes between two kinds of cognitive abilities: The first one refers to communication and instruction and is general because it applies onto a multitude of learning tasks; the other kind of cognitive abilities are specific with regard to a particular learning task. In addition to the aforementioned factors, another learner-specific factor plays a significant role within Carroll's model, namely *perseverance.*

In addition to the learner-specific factors, the actually spent time for learning is constrained by the time allowed for task learning, i.e., the *opportunity to learn.* This is dependent on the teacher or the curriculum but also on grouping or individualization in order to homogenize learning speed and the contents to be learned. Instructional decisions determine also the sequencing of learning tasks influencing the student's opportunities to learn. The degree of the teacher's adjustment to particular needs and characteristics of the learners by means if adequate sequences of learning steps are provided is a central part of the quality of instruction.

In sum: The time actually spent for learning corresponds with the smallest of the three factors: time allowed for learning, perseverance, and required time for learning. The time allowed for learning can be smaller or bigger than the required time for learning. However, the time actually spent for learning is also constrained by (a) the time a learner is motivated to spend for accomplishing a task, (b) the perseverance, (c) the time needed for accomplishing the task, and (d) the learner's aptitudes. Consequently, a learners stops learning when the time allowed for learning is too short or the motivation for learning is not sufficient.

Important Scientific Research and Open Questions

Carroll's model of school learning was the fundamental basis for a number of follow-up attempts to identify and structure the primary variables of effective school learning. Nevertheless, it has been criticized due to some shortcomings. For example, Harnischfeger and Wiley (1978) criticizes the model as individualistic inasmuch as it refers only to one learner and one learning task. It neither incorporates the classroom as sum of individuals nor the sequencing of different interrelated learning tasks nor the curriculum as an entity. Rather, the quintessence of the model consists in the fact that the factors aptitude, opportunity for learning, and perseverance are expressed in terms of measured time.

A major aspect of Carroll's argumentation is the precept that the teacher should focus on controllable variables constituting the quality of instruction. Accordingly, some follow-up models of school learning addressed additional classroom and school-level variables. So, for example, Squires et al. (1983) relabeled "perseverance" with "involvement" and they added "coverage" (defined as overlap of the content taught and content tested) and "success" (defined as degree of achievement in performing academic tasks).

Another alteration of Carroll's model is the QAIT model of Slavin (2006), in which Q denotes the quality of instruction in Carroll's sense. A refers to the appropriate levels of instruction by redefining student's aptitude and ability to understand instruction in terms of teaching behavior variables. I is the abbreviation of "incentive" and replaces perseverance through a teacher behavior variable. Finally, T stands for time and corresponds with Carroll's original variable of opportunity to learn. It is not the place here to justify these different approaches in more detail. It is sufficient to show that Carroll's model was influential enough to evoke follow-up and alternative conceptual models for school learning.

Most important is the observation that the variables "time spent" and "perseverance" of Carroll's model have been replaced through the concept academic learning time conceived in general as a combination of content overlap, involvement, and success. Academic learning time revealed as an appropriate time variable for research (Berliner 1978) due to the fact that it is directly influenced by classroom variables and is the result of many decisions about how much time is spent for learning in the classroom.

Cross-References

- ► Academic Learning Time
- ► Bloom's Model of School Learning
- ► Learning Tasks

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Case-Based e-Learning

► Case-Based Learning on the Web

Case-Based Learning

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Synonyms

CBL

Definition

Case-based learning (CBL) is a pedagogical concept, where *work method*, *problem*, and *discipline* are identified by the learner (or learners) through the learning process. Case-based learning is oriented toward a case, which from different perspectives generates different and equally correct problems. Case-based learning is about choosing, deciding priorities, and combining different disciplines, and as such is best practiced in a multidisciplinary context.

Theoretical Background

Back in the early 1990s, the term case-based learning was often synonymous with case-based reasoning, which means reasoning based on remembering previous experiences (e.g., Kolodner 1993). This understanding of case-based learning was based on ► machine learning.

Today, case-based learning is usually emphasized as a special kind of problem-based learning. However, the first clear definition, with a systematic distinction and inclusive relation to problem-based learning, solution-based learning, and definition-based learning, was not made until 2008 (Kjærulff et al. 2008). This time, case-based learning was perceived as an answer to the challenge of developing a multidisciplinary study across three faculties at Aalborg University, Denmark, where problem-based learning had been practiced in all study programs since the early 1970s.

Case-based learning takes the preconditions of problem-based learning a step further. In problem-based learning, both *work method* and *problem* are identified by the learner through the learning process. In study programs where conventional problem-based learning is practiced, the blind spot is the inherent perspective in the discipline and how they may influence the studies. The pedagogical philosophy of problem-based learning asserts that a study project will never be better than the problem investigated. However, it is implicit – though not stated – that this investigation must be within the discipline and related paradigm of the study.

In modern society, common challenges have to be met with a multidisciplinary approach (Qvortup 2003). Different perspectives on the same phenomena, or case, result in different problems. Or more accurately: The truth is inherent in the perspective, and all perspectives might be equally correct (Rosenstand 2008). There is not one privileged and valuable truth. In practice – both in science, industry, and life in general – all cases benefit from being approached from multiple perspectives. In a society where knowledge is essential and highly valuable, more knowledge is produced by addressing a case from different disciplines. Thus, it is essential that pedagogical concepts which address multidisciplinarity are introduced and used as part of modern study programs – Case-Based Learning is such a concept.

In order to address the blind spot of problem-based learning, *discipline* is added to *work method* and *problem* as a pedagogical component that the learner has to identify through the learning process. A simple cross tabulation of pedagogical concepts with pedagogical components results in Table 1, including solution- and definition-based learning.

A plus ("+") in Table 1 marks that the learner is provided with a pedagogical component as part of the learning process, and a minus ("–") marks that the learner has to identify the pedagogical component through the learning process.

Case-Based Learning. Table 1 Cross tabulation of four pedagogical concepts with three pedagogical components

Pedagogical component / Pedagogical concept	Work method	Problem	Discipline
Definition-Based Learning	+	+	+
Solution-Based Learning	–	+	+
Problem-Based Learning	–	–	+
Case-Based Learning	–	–	–

In definition-based learning, the learner is provided with *work method, problem*, and *discipline.* It is a *routine learning situation*, where the learning process has a permanent form. Definition-based learning is good for providing the learner with *qualifications* in situations where the ability to *produce solutions* is essential.

In solution-based learning, the learner is provided with both *problem* and *discipline.* However, the learner has to identify the *work method* through the learning process. It is a *problem-solving learning situation*, where the learning process has a solid but not permanent form. When the learner has identified a *work method*, the learning situation shifts to a routine learning situation, where the *work method* is identified and provided by the learner. The learner might discover that the *work method* is not too wise and turn back to a problem-solving situation conducting solution-based learning once more. In this way, definition-based learning is included in solution-based learning, at least as a precondition for producing a solution. Solution-based learning is good for providing the learner with *competences* in situations where the ability to *choose solution methods* is essential.

In problem-based learning only the *discipline* is provided to the learner. As the paradigm behind the study often is inherent in the study culture, it is rarely questioned as the correct perspective. The learner has to identify *work method* and *problem* through the learning process. It is a *problem-oriented learning situation*, where the learning process has a loose but not unpredictable form. This is often termed a problem-oriented pedagogy, where the learner has to orientate himself toward a problem. When the learner has identified a problem, the situation shifts to a solution-based learning situation, where the *problem* is identified and provided by the learner. The learner might find out that the *problem* is not sufficiently fertile, because the identification of the *work method* is either too simple, or too complex, in relation to the *problem* – or the identified *work method* in relation to the *problem* results in a trivial outcome when shifting to the routine learning situation. In this case, the learner can turn back to a problem-oriented situation conducting problem-based learning. In this way, problem-based learning includes solution- and definition-based learning. Problem-based learning is good for providing the learner with *creativity* in situations where the ability to produce *new solution methods* is essential.

In case-based learning, the learner has to identify *work method, problem*, and *discipline* – none of the pedagogical components are provided to the learner. It is an *innovative learning situation* where the learning process has an unpredictable form; in this sense, case-based learning is a medium in which all the pedagogical components can take different forms. A *discipline* has to be identified through a process in which different disciplines and their inherent perspectives are chosen, prioritized, and combined in an interdisciplinary process, where the different perspectives benefit from a negotiation in a multidisciplinary context. Only geniuses can do this alone – and not always with all the relevant perspectives. Actually, we do not know which *discipline* will prove fertile until we know and understand the very essence of a case, and this includes the shift through a problem-oriented, problem-solving, and routine learning situation, where problem-, solution-, and definition-based learning is conducted, respectively. The identified *discipline* might turn out to generate or require *problems* and/or *work methods* that are either too simple or too complex. In this case, the learner, and the group of which he is usually a part, will turn back to an innovative learning situation, where the *discipline* has to be renegotiated in order to include new – and perhaps exclude old, perspectives. This requires an open and flexible study culture. As exemplified, case-based learning includes problem-based learning, which again includes solution- and definition-based learning. Below, brackets are used to illustrate how a pedagogical concept includes another pedagogical concept:

- Case-based learning (Problem-based learning (Solution-based learning (Definition-based learning)))

Case-based learning is good for providing the learner with *culture*, where the ability to s*et up a new framework – a new perspective* – is essential. Case-based learning adds an extra dimension to the education of the learner because in order to participate in the required open learning culture, he has to accept that other perspectives than his own can be equally correct, even if the different perspectives seem incompatible.

Table 2 sums up the characteristics of the four pedagogical concepts.

The relationship between the knowledge forms qualification, competences, creativity, and culture is built on ► Greagory Bateson's "four levels of learning" (Qvortup 2003).

Important Scientific Research and Open Questions

Only very few study programs have practiced case-based learning as defined in this entry. As such, it is a new theory of learning that has yet to be discussed in the literature. However, there is comprehensive scientific research in the closely related field of ► problem-based learning.

Case-Based Learning. Table 2 Major characteristics of the four pedagogical concepts

Pedagogical concept	Learning situation	Learning process	Knowledge form
Definition-Based Learning	Routine	Permanent form	Qualification
Solution-Based Learning	Problem solving	Solid form	Competences
Problem-Based Learning	Problem orientation	Loose form	Creativity
Case-Based Learning	Innovation	Unpredictable form	Culture

Different organizational study forms have yet to be developed and experimented with. How is motivation and talent combined in an interdisciplinary learning culture, where students have to take an interest in areas other than the one that has their initial interest?

Where and when is case-based learning a wise approach? It has been tried out at university level in different courses, semesters even, with some success; but it has not been tried out as the overall pedagogical concept for an entire bachelor or candidate program. Should such an experiment be conducted, it would be necessary to include several study programs simultaneously in order to ensure the multidisciplinary preconditions.

Other open questions are: If case-based learning is conducted, how much weight should this approach carry compared to the other pedagogical approaches in higher education? Will it apply in certain cases only? When? Could public schools and colleges benefit from case-based learning? How? And how does case-based learning apply to an industrial context as a pedagogical approach that supports innovative processes?

Cross-References

► Bateson, Gregory (1904–1980): Anthropology of Learning
► Complex Problem Solving
► Cooperative Learning
► Creativity, Problem Solving, and Feeling
► Cross-Disciplinary Learning
► Culture of Learning
► Guided Discovery Learning
► Machine Learning of Natural Language
► Problem Solving
► Problem-Based Learning

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Case-Based Learning on the Web

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Synonyms

Case-based e-learning

Definition

Case-based learning on the web (CBLW) occupies the intersection of case-based learning and online learning. There is scant research on CBLW specifically; what exists is mainly in the field of health sciences education, and medical education in particular. CBLW prepares the learner for authentic and *situational* performance, rather than presenting *canonical* technical learning through a straightforward instructional demonstration video on the web. CBLW is also distinct from case studies of online learning as a pedagogical method.

In the medical education literature, CBLW is typically implemented through a free-standing educational module, or a set of modules, which the learner accesses and engages with, via the web through a computer or similar device, and which is based on a specific and highly realistic scenario. It typically uses audio and video components, in addition to text, illustrations, and other media, and can include assessment of the learner as well as assessment of the web-based curriculum itself. The student may be allowed to experience the module in a free-flowing path, choosing to navigate in any direction, or forced to be linear, with a "one-way" direction, or even through the use of a selective release mechanism, whereby a student must verify completion of one section, with perhaps a quiz, before being allowed to move to the next section. It usually is designed to push the learner to engage with the material, making reasoned decisions along the way, applying previously learned general principles to the case at hand, and creating new general hypotheses from the case.

Theoretical Background

CBLW combines the features of simulation-based learning (case-based), with ready access (online learning). Furthermore, CBLW can standardize learning in content and quality, facilitate active learning by the student, avoid the cost of staging multiple or repeated simulations, and can allow asynchronous learning for learners dispersed amongst temporally or geographically distributed learning environments, such as medical students who are assigned to clinical experiences at different times and clinical locations. Because it can capture and record learner responses, CBLW can assess the learner's level of competency around elements of the case. CBLW need not exclude real-time exchange with instructors or fellow learners; there can be designated times for synchronous participation and learning, such as required completion of a CBLW activity prior to a scheduled online discussion. Asynchronous or elective use of a CBLW allows for on-demand learning, either just-in-time learning, or as needed out of curiosity, for a repeated experience, or reference.

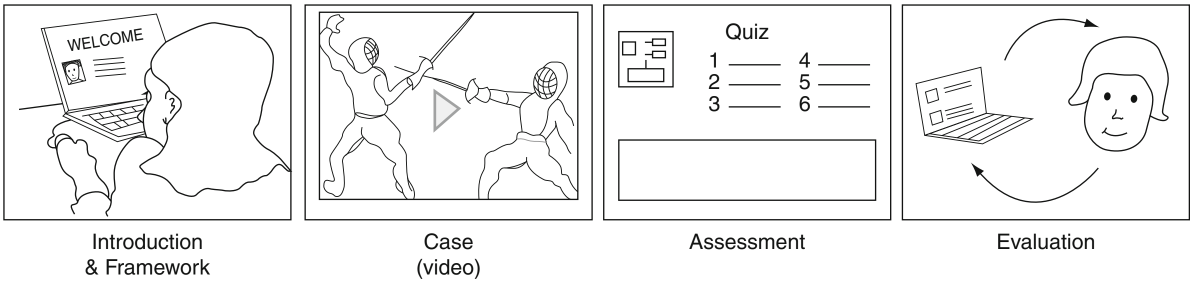
CBLW may become more essential to formal learning as virtual learning environments become more commonplace in conventional schools and "evening schools," and with the rise of new, accredited schools designed to be completely virtual. This modality represents a bridge of five unique areas of expertise: (1) educational pedagogy, (2) content and skill expertise, e.g., clinical reasoning, (3) video production, (4) case construction, and (5) web technology. Collaboration amongst those who together have expertise in all five critical areas is essential for high-quality CBLW. CBLW must be based upon a solid foundation of curriculum development, and well-established education principles must be applied, for example, active learning, activation of prior knowledge, constructivism, and feedback.

How CBLW differs from conventional learning methods, such as a lecture or classroom small group, is exemplified by the utility and near necessity of storyboards in the curricular design process. The storyboarding process, as practiced today, was developed at Walt Disney studio during the 1930s. The Disney approach developed storyboarding as a visual design and collaboration system. It is now used wherever people collaborate to produce media-rich projects especially in video cases, interactive media, and E-learning. It is a design method used in the creative arts to shape the content from the learner's perspective. It is similar to the architect's small-scale model of a building but adds the dimension of time or flow. A storyboard is both a method for collaborators to communicate about the design and experience its function, as well as the platform which learners will access, navigate, and use. Conceptual storyboards illustrate on paper what is imagined as the actual computer screen images, combined with exactly how the learner interacts with the material: starting, pausing, navigating. Each frame or page of the conceptual storyboard is visual in nature. Production storyboards document the flow of the module and can be either in the form of pictograms or text, analogous to a program book, table of contents, or sitemap. This leads to effective CBLW, where the student actually *experiences* the problems illustrated by the case, rather than *learns about* the problems of the case (Fig. 1).

CBLW is more dynamic than a textbook and allows for ongoing content updates, providing students with up to date content. This format allows the inclusion of images, video, audio, and animation. Multimedia helps target different learning styles and can be tailored to content. Expanded references are instantly available using web links. The web is flexible and becoming easier to use with more tools such as Wikis, blogs, and web sites which only require an HTML coder. The web is searchable and can readily archive learning objects such as cased-based modules. There are a growing number of existing platforms, software building blocks, and digital technologies that make the design of E-learning tools faster and less costly.

Important Scientific Research and Open Questions

There is a paucity of scientific research on CBLW. There is far more research on E-learning in general, emerging from reviews of health education studies (Chumley-Jones et al. 2002; Ruiz et al. 2006; Cook 2007; Wong et al. 2010). Their reviews and summaries, based on studies that include some CBLW, point out that curricula must be well-designed curricula regardless of mode; that E-learning is not intrinsically superior in either learning outcome or learner satisfaction; that it can be



Case-Based Learning on the Web. Fig. 1 Example of a simplified version of storyboarding

cost-saving; and that since the internet is here to stay, so is E-learning, including its CBLW variant. Wong proposes a set of questions related to technology acceptance and achieving interactive dialogue for educators to address to maximize effectiveness and perceived usefulness. The five questions are: How useful will the prospective learners perceive the Internet technology to be? How easy will the prospective learners find this technology to use? How well does this format fit in with what learners are used to and expect? How will high-quality human–human (learner–tutor and learner–learner) interaction and feedback be achieved? How will high-quality human–technical interaction and feedback be achieved?

One of the few studies of CBLW specifically is also from the medical education literature (Nathoo et al. 2005), and its findings include higher levels of student engagement and relationships with faculty and accountability to the learner peer group compared to the classroom problem-based learning tutorial format. CBLW also provided benefits of self-selected student pace and more realistic student experiences. Nathoo et al. suggest the need for developing new metrics for measuring level of student collaboration outside the classroom, and evaluation systems that test higher levels of abstraction, beyond simple recall of factual information, and that measure authentic challenges and competencies that medical practitioners face.

Applying research on E-learning to CBLW suggests that there are important limitations. It is not a replacement for learning through real case-based practice such as piloting an airplane or working with a patient, but is effective as preparation for real practice. The actual mentor–learner relationship is lost, though this is mitigated in those cases when the module is used for synchronous or asynchronous learning with the teacher. Similarly, the social context of learning with peers is lost, and only partly realized if the module is used to engage with other students. That the learning is on the web, as opposed to a classroom or typical workplace, increases the possibility of the learner to be distracted simultaneously by other web-based and electronic activities, such as e-mail, web-surfing, music, and other entertainment. On the other hand, the web can also provide access to instant and unlimited sources of learner-centered reference materials, which may enhance case-specific learning. The effect on learning by the increased availability of all these types of distraction, and subsequent decrease in singular focus on the case-based module, is unknown.

The future of the web, including its capacities and how it is accessed, will lead to intriguing possibilities for the design and use of CBLW. Mobile web access via increasingly portable equipment, web-based social learning platforms and culture, and the development of artificial intelligence web applications will greatly expand the scope of how and for what educators and learners can use case simulations on the web. For example, in the health-care education and practice arenas, the emergence of the electronic medical record, artificial intelligence–derived real-time guidance and projected health outcomes based on gaming theory, instant access to patient study results, and virtual communication with patients and other members of the health-care team may converge with simulation-based learning. CBLW may someday even transform into personalized, real-time learning that is no longer simulated, but instead a form of web-enabled augmented reality.

Cross-References

► Active Learning
► Assessment in Learning
► Asynchronous Learning

- ▶ Audiovisual Learning
- ▶ Blended Learning
- ▶ Case-Based Learning
- ▶ Computer-Based Learning
- ▶ Distributed Learning Environments
- ▶ e-Learning and Digital Learning
- ▶ Evaluation of Student Progress in Learning
- ▶ Learning by Doing
- ▶ Learning from Video
- ▶ Online Learning
- ▶ Problem-Based Learning
- ▶ Simulation-Based Learning
- ▶ Technology-Based Learning
- ▶ Twenty-First-Century Skills
- ▶ Video-Based Learning
- ▶ Virtual Learning Environments

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Case-Based Reasoning

- ▶ Analogical Reasoning
- ▶ Schema-Based Reasoning

Categorical Analysis

- ▶ Categorical Representation

Categorical Learning

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Synonyms

Categorization; Category learning; Classification

Definition

From bacteria categorizing a molecule as nutrient or poison to humans categorizing individuals as friend or foe, categorical learning is a process that is vital for the existence of any organism. More formally, categorical (or category) learning is the process of establishing a memory trace that improves the efficiency of assigning novel objects to contrasting groups. In addition to facilitating the categorization of objects, categorical knowledge also facilitates a variety of cognitive processes.

In defining categorical learning, it is useful to consider what it is not. One important distinction is between categories and concepts. A category is a collection of related objects (from a single or multiple stimulus modalities). A concept, in contrast, is a collection of related ideas. Another important distinction is between novel and well-learned categories. The rules that govern the learning of novel categories and the access of information from well-learned categories are likely quite different. For instance, patients with neurological damage resulting in the loss of a well-learned category (e.g., tools as in one type of category-specific visual agnosia) do not lose the ability to learn novel categories. Also, patients with neurological damage resulting in a categorical learning impairment (e.g., patients with Parkinson's disease) do not lose well-learned categories.

Theoretical Background

Since antiquity, categorical learning has been thought to be a central ability underlying cognition. Not surprisingly, categorical learning has been one of the most thoroughly studied areas of ▶ cognitive psychology.

Theories of categorical learning, however, did not obtain prominence until the seminal work of Bruner et al. (1956) at the dawn of the cognitive revolution. The work of Bruner and colleagues can be traced back to the Greek philosopher Aristotle and postulates that categories are represented by their defining attributes. Defining attributes are the set of singly necessary and jointly sufficient features for category membership. Although, this so-called classical theory continues to be highly influential, its shortcomings are widely accepted. For instance, there are many categories for which it is difficult, if not impossible, to list the necessary and sufficient features (e.g., games). In addition, classical theory incorrectly predicts that all category ▶ exemplars are equally representative category members.

Prototype theory was proposed as an alternative to classical theory (Rosch and Mervis 1975). According to prototype theory, the category ▶ representation consists of the most typical member of the category (i.e., the ▶ prototype) and the categorization of novel exemplars is based upon similarity to the prototypes of contrasting categories. Prototype theory, unlike classical theory, predicts that category membership is graded and, as a result, captures the well-documented finding that some category members are more typical than others. Although economical, the assumption that the category representation is restricted to only the most prototypical member is rather limiting. For instance, information about variability and correlational structure within a category has been lost.

Exemplar theory, in contrast, provides a richer category representation by assuming that the categorization of novel exemplars is based upon similarity to the stored representations of all previously experienced instances of the contrasting categories (Nosofsky 1986). The high resolution of the category representation enables exemplar theory not only to predict the phenomena accounted for by prototype theory, but also to predict effects that are dependent upon within-category variance and correlation such as the influence of category members that are far from the prototype. An additional contribution of exemplar theory was to formally incorporate a mechanism for selectively weighting some stimulus dimensions over others (i.e., ▶ selective attention). One enduring criticism of exemplar theory is based on the assumption that every exemplar is stored in memory. Given current knowledge of the neural substrates of memory formation, this assumption is implausible as a general feature of categorical learning.

At the same time exemplar theory was gaining prominence, decision-bound theory (based upon general recognition theory, Ashby and Townsend 1986) was also being developed. Decision-bound theory is a multivariate generalization of signal-detection theory. It is assumed that, on each trial, the perceived stimulus can be represented as a point in a multidimensional psychological space and that each participant partitions the perceptual space into response regions by constructing a decision bound. The participant determines which region the perceived stimulus is in, and then makes the corresponding response. An important contribution of decision-bound theory is that it separates perceptual and decisional influences on categorical learning. Thus, selective attention, for example, can affect the perceptual representation of the stimulus as well as how stimulus dimensions are weighted in making categorization decisions.

Decision bounds can take many different forms and, therefore, can mimic other theories of categorical learning. One class of decision-bound models assumes that independent decisions are made about all (or some subset) of the stimulus dimensions. Such models are closely related to classical theory and have led to the development of so-called rule-based theories of categorical learning. According to rule-based theories, logical expressions are used to evaluate category membership (e.g., if the stimulus has a value on dimension X greater than some decision criterion, it belongs in category A; otherwise it belongs in category B). Thus, rather than a list of defining attributes, the category representation is simply the decision criterion. Another class of decision-bound models assumes that the decision boundary is midway between the categories. Such models are generally equivalent to prototype models because the same categorization response would be predicted regardless of whether distance to the category boundary or distance to the category prototypes is used to make a decision. Although decision-bound theory can mimic other theories of categorical learning, the fundamental category representation is restricted to the decision boundary thereby limiting decision-bound theory as a general theory of categorical learning.

Although these divergent theoretical perspectives have been hotly debated for more than 50 years, it is difficult for any theory to claim victory. Arguably, exemplar theory has been the most popular of the categorization theories. It is important to note, however, that mathematical models derived from prototype and decision-bound theory have often been shown to outperform, or perform equivalently to, models derived from exemplar theory. For instance, when prototype models make the more realistic assumption that a category has multiple prototypes (rather than a single prototype) many of the aforementioned criticisms of prototype theory are resolved.

It is important to stress that all of these theories make an important contribution. Indeed, many researchers have embraced the idea that the "correct" theory, or ► system, varies depending upon the particular categorization task. This is not too surprising given that most studies advocating a particular theoretical perspective tend to investigate the same type of categorization task. For example, exemplar theory has enjoyed considerable success in accounting for data from categorical learning tasks where memorization is plausible given the small number of category exemplars. Similarly, decision-bound theory has enjoyed considerable success in accounting for data from categorical learning tasks where memorization is implausible given the large number of category exemplars.

The idea that distinct learning systems contribute to categorical learning has been suggested by many researchers over the last 30 years (e.g., Ashby et al. 1998). Multiple systems theorists generally agree that one system is rule-based. Differences between alternative theories center on how best to characterize the other system(s), in particular, issues related to the nature of the category representation (e.g., exemplar vs. prototype).

The argument for multiple categorical learning systems has been fueled, in large part, by the fields of behavioral and ► cognitive neuroscience. Such research has generally focused on three types of categorical learning tasks. Rule-based tasks are those in which the categories can be learned by an explicit reasoning process using logical rules. Information-integration tasks are those in which logical rules have limited success and, instead, accuracy is maximized by combining information from two or more stimulus dimensions prior to making a categorization response. Prototype-distortion tasks are those in which the category members are generated by randomly perturbing the category prototype. Prototype-distortion tasks typically instruct participants to distinguish between category members and nonmembers (i.e., A-not A tasks), but it is not uncommon to use two contrasting categories (i.e., A-B tasks). Numerous behavioral dissociations between these tasks support the utility of this task-based taxonomy. It is important to note, however, that although different categorical learning systems may be better suited to learn a particular task, there can be considerable individual differences in how participants learn these tasks.

Cognitive neuroscience research utilizing neuroimaging and neuropsychological methdologies indicate that categorical learning in these three types of tasks relies upon different neural circuits. Rule-based tasks have been shown to depend upon lateral prefrontal cortex and anterior regions of the ► basal ganglia. Information-integration tasks have been shown to depend upon a neural circuit linking high-level, sensory cortical areas (e.g., inferotemporal cortex in the case of visual stimuli) to high-level motor areas (e.g., premotor areas) via posterior regions of the basal ganglia and the thalamus. A-not A prototype-distortion tasks depend upon extrastriate visual cortical regions whereas A-B prototype-distortion tasks also depend upon prefrontal and parietal cortices.

Important Scientific Research and Open Questions

Multiple systems theorists are faced with at least two critical challenges. The first centers on characterizing categorical learning systems. In pursuit of this task, researchers must carefully define criteria for determining whether a putative system is, in fact, a separate system or run the risk of system proliferation. Importantly, characterizing systems not only requires specification of the cognitive processes, but also the neural substrates. As systems are characterized, the challenge of understanding how they interact becomes paramount. Current theories assume that categorical learning systems operate in parallel and compete with each other, but there is little data to rule out other types of interactions (e.g., cooperation). Even if competition is the correct assumption, there is very little data to guide theorizing on how competition is resolved on a trial-by-trial basis.

Historically, cognitive psychology has been insular in its study of psychology and the study of categorical learning has been no exception. Recent research has embraced classic findings from other disciplines within psychology and is beginning to incorporate these ideas into theorizing on categorical learning. For instance, categorical learning is influenced by an individual's motivation for performing the task and how these motivations match the task incentives. In addition, it is now apparent that the ► social stressors we encounter in our daily lives can have a profound influence on categorical learning. Whether social stressors impair or enhance categorical learning depends upon the type of categorization task. Currently, there is no mechanism within purely cognitive theories of categorical learning, or cognitive neuroscience theories, to adequately explain these data.

A thorough understanding of categorical learning requires an appreciation of differences in training methodology. The vast majority of studies that have guided theory development can be classified as supervised learning studies in which a trial consists of stimulus presentation, categorization response, and corrective feedback. In contrast, unsupervised learning studies omit corrective feedback. Another popular methodology requires the participant to use the value of the stimulus on a subset of the dimensions and the correct category label to infer the value of the stimulus on a missing dimension. These methodologies have been used in isolation or hybridized in various ways. Importantly, however, the choice of methodology can have a profound impact on the category representation (Markman and Ross 2003). For example, the category representation resulting from unsupervised training is restricted to be rule-based. In addition, supervised training enhances the representation of between-category differences whereas inference training enhances the representation of within-category similarities. Together, these training methodologies constitute a powerful set of tools to study categorical learning.

Cross-References

► Categorical Learning in Pigeons
► Categorical Representation
► Concept Learning
► Explicit and Procedural-Learning Based Systems of Perceptual Category Learning
► Explicit Versus Implicit Learning
► Mathematical Models/Theories of Learning

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Categorical Learning in Pigeons

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Synonyms

Concept learning in pigeons; Pigeon classification behavior

Definition

Categorical Learning in Pigeons refers to the process by which these animals come to treat different stimuli equivalently, as members of a single class. Evidence of this learning would require affirmative answers to these three questions: can pigeons respond differently to members of different classes of stimuli, can pigeons respond similarly to members of the same class of stimuli, and can pigeons transfer these behavioral tendencies to novel instances of the relevant categories? Pigeons can indeed categorize stimuli in these ways when class membership is defined by a variety of criteria, including perceptual resemblance, common associations with an event, and abstract properties of stimulus collections.

Theoretical Background

From the earliest experiments on category learning in pigeons, this area of behavioral research has centered on the question: Do pigeons use anything akin to human concepts to learn categorization tasks? Answering this question has involved contending with several challenging issues, which has shaped the field into a unique approach to the study of categorical and conceptual behavior.

The prime issue is that there is little consensus in the human and animal literatures as to what constitutes a *concept*. Indeed, some definitions of concepts are so directly tied to a fully operational human linguistic system that they deny the possibility of animal concepts *ipso facto*. Other definitions assume that abstract concepts arise from a particular cognitive architecture; indeed, some researchers envision concepts to be discrete symbols through which the rules of language and propositional thought can operate. For such definitions, a test for the presence of concepts in animals may be needlessly stringent, given that it is also a test for other properties of these cognitive architectures.

Most of the empirical research in pigeon categorization has arisen from an entirely different approach to the definitional issue. This approach involves trying to identify the kinds of behaviors and cognitive processes to which we refer when we talk about concepts, instead of trying to grasp the essence of concepts through an abstract definition (Critchfield et al. 2002). Thus, research is centered on *conceptual behavior* and *conceptual processing*, both deemed to be natural phenomena which require a scientific explanation.

This operational strategy involves focusing on specific behavioral tests which are indicative of conceptualization as well as identifying the prior conditions that allow animals to pass these tests. Several tests of conceptualization have been proposed, in some cases suggesting a system of *types of concepts* or categories with different levels of abstractness (Herrnstein 1990). For example, the transfer of responding to novel instances of a class is taken to be the hallmark of "open-ended" category learning, allowing organisms to go beyond the memorization of individual stimuli. In this way, the units of analysis in the study of animal conceptual behavior are determined empirically, in contrast to the tradition of research in human conceptualization where the units of analysis are identified *a priori* through lexical concepts (see the article by Palmer in Critchfield et al. 2002). Within this latter framework, concepts as mental structures are considered to be explanatory principles which can be used to account for the observed behavior. Following a long tradition in the application of Morgan's canon of parsimony to the explanation of animal behavior, many researchers reject the presence of concepts in pigeons because the behavior that is used to infer concepts may be explicable through "lower-level" mechanisms (Mackintosh 2000).

Because animals are assumed to have little or no prior experience with the kinds of categories that are taught to them in categorization experiments, the research focus concerns the conditions that foster category or concept *learning*, in contrast with an important part of research in human concepts which focuses on studying how people represent and use already acquired knowledge (Critchfield et al. 2002). In sum, research on pigeons and other animals not only constitutes a subfield of a much larger research realm in categorization and conceptualization, but it entails an altogether different approach to the study of these topics.

Although the question of whether pigeons use something similar to human concepts to solve categorization tasks is still open to debate, research in the area has generated an important body of knowledge about the categorization abilities of these animals (for a review, see Lazareva and Wasserman 2008). This research is roughly organized in three areas, depending on the criteria that are used by researchers to group together members of a class: perceptual, associative, and abstract category learning.

In perceptual categorization, pigeons classify stimuli on the basis of their perceptual similarity. Almost all of this research has focused on visual stimuli and naturalistic classes defined by human language, such as "people," "flowers," "cars," and "chairs." Pigeons can correctly classify photographs of these objects and transfer this classification learning to novel instances of the categories. Accuracy to novel stimuli in transfer tests is often reliably lower than to familiar stimuli, suggesting that stimulus properties which are diagnostic of the categories are not alone in controlling performance; idiosyncratic properties of the particular training stimuli may also control performance. One factor which increases accuracy to novel transfer stimuli is the size of the training set. A larger number of training exemplars leads to slower learning, but it also leads to higher levels of generalization to novel stimuli.

There is important evidence indicating that pigeons can spontaneously detect the perceptual cohesiveness of natural categories even if they are not required to do so in order to earn reinforcement. Thus, when pigeons learn that members of one category are associated with a response, they more robustly generalize this response to other members of the same category than to members of different categories. Also, pigeons seem to exploit this perceptual cohesiveness during categorization training, as suggested by their quicker learning of tasks in which all members of the same category are assigned to the same response than their learning of tasks in which the stimuli are randomly assigned to the discriminative responses.

The behavioral mechanisms of category learning in pigeons are flexible enough to allow the concurrent classification of the same stimuli into their basic *perceptual* classes and into *superordinate* classes created by the union of two natural categories (e.g., the class of "man-made objects," created by "chairs" and "cars"). There is also evidence indicating that these behavioral mechanisms can involve pigeons' reliance on category-relevant features of the stimuli which additively combine to support a particular response: for example, wheels, a body, and a roof prompt the recognition of a car. Finally, there is growing agreement that these behavioral phenomena are largely governed by the same principles that are at work in associative learning and stimulus generalization, although until recently there has been little effort to support this claim either theoretically or empirically.

In associative category learning, pigeons group stimuli on the basis of their association with a common response or some other event, in much the same way that we come to call shoes, pants, and hats items of "clothing." After training of such common associations, if pigeons learn to give a new response to some stimuli from the original training set, then this new response may generalize to all of the other members of the class. Such generalization is taken as evidence of pigeons' ability to acquire an *equivalence class*, where stimuli are treated equally, not on the basis of their perceptual resemblance, but on the basis of their common training contingencies. There is also evidence suggesting that after being associated with the same experimental outcome, stimuli belonging to the same equivalence class start sharing a common representation. Now, those stimuli become more difficult to discriminate from each other than would otherwise have been the case.

In abstract categorization learning, pigeons come to sort stimuli into classes on the basis of abstract relations among stimulus elements. Perhaps the simplest form of discrimination of abstract stimulus features is relational learning. Here, pigeons learn to respond to stimuli on the basis of their relative position in a physical dimension ("larger than" or "brighter than") instead of their absolute value along that dimension. Although traditional demonstrations of relational learning in pigeons can be explained as arising from the interaction of absolute associative values, recent evidence has questioned the generality of that explanation.

Pigeons have also shown the ability to discriminate collections of items on the basis of their variability, that is, the degree to which the items composing an array repeat or vary from each other (Wasserman et al. 2004). So, after training to discriminate arrays of 16 items on the basis of whether all of the items are identical or nonidentical, pigeons can be tested with novel arrays involving *mixtures* of identical and nonidentical items. Here, the likelihood of pigeons' responding "nonidentical" to the mixtures increases with the variability in the test array. Still other evidence suggests that such variability discrimination may lie at the root of the twin concepts of "same" and "different."

Finally, there is evidence showing that pigeons can also learn to match stimulus collections on the basis of the second-order relations between them. Thus, pigeons learn that after being shown a 16-item sample display with a particular relation among its elements (either all of the elements are identical or all of the elements are nonidentical), they must choose another display exhibiting the same relation among elements (either identical or nonidentical). Such *relational matching-to-sample* may represent a form of analogy.

Across all of these different categorization tasks, a common factor which increases the likelihood of generalization to novel exemplars of the category is the number of trained stimuli. Larger training sets lead to better evidence of abstract learning. One interpretation of this result is that experience with several exemplars from each category is necessary for detecting the abstract properties of the stimuli. Without such rich experience, the pigeons might pay attention to more concrete perceptual features, which are irrelevant to task solution. Another possibility is that a large number of training stimuli simply increases the likelihood of a test stimulus being perceptually similar to one or more of the training stimuli. Considerable work has explored these two possibilities.

Important Scientific Research and Open Questions

In the past, considerable research and discussion have focused on determining whether pigeons and other nonhuman animals use something like human concepts in mastering categorization tasks. This anthropocentric line of research paid little attention to the possibility that different *types* of conceptual processing exist in nature. However, empirical results have forced researchers to consider just such a possibility. Future research is likely to focus more on determining what kinds of conceptual processes pigeons and other animals exhibit and to disclosing similarities and differences in these processes across diverse species. Expanding the scope of research toward studying more categorization tasks and more species is likely to be crucial to gain a better understanding of the evolution of conceptual processes.

Current research in the area of pigeon categorization is quickly shifting from studies aimed at discovering pigeons' categorization abilities to studies aimed at pinpointing the mechanisms underlying these abilities. Recent research has prompted several accounts of pigeons' categorization behavior, some of them formalized in quantitative models. Future research and theory will likely move beyond behavioral comparisons across species and toward deeper comparisons involving the mechanisms of categorization.

Cross-References

► Animal Learning and Intelligence
► Association Learning
► Categorical Learning
► Comparative Psychology and Ethology
► Similarity Learning

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Categorical Perception

Categorical perception is defined as an "abrupt perceptual change at the boundary" (Harnad 2005), which can be seen in situations where the perceived change in some attributes (e.g., color) does not occur gradually but as instances of different categories.

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Categorical Representation

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Synonyms

Categorization; Categorical analysis

Definition

The origin of the term "categories" is the Greek word "Κατηγορίαι" (Katēgoriai), which refers to the manuscript written by Aristotle, wherein he defined ten fundamental modes (categories) of being (things), namely substance, quantity, quality, relative (relation), somewhere (location), sometime (when), being-in-a-position, having (state), acting, or being affected (Ackrill 1975). The word "representation," as defined by the Oxford English Dictionary, means "the action or fact of expressing or denoting [a thing] symbolically." Categorical representation can be described as the process of expressing things in different modes and layers of abstraction based on similarities and differences in their attributes and relations. Categorical representation has been a subject of study in knowledge representation, mathematics, cognitive science, linguistics, philosophy, psychology, art, and so forth. Members of a category have common attributes and together represent perceptual or conceptual knowledge about a particular domain of interest.

Theoretical Background

The human brain has the ability to organize the details of perceived objects within a series of categories based on their common features. Similarly, the objects in the real world can be processed (i.e., compared, evaluated, and remembered) by the brain, based on known attributes and past experiences. This allows people to incrementally acquire new knowledge (e.g., discriminating between life-threatening situations versus safe ones) and communicate with each other through the shared conceptualization of the subject. Therefore, the process of categorization is important for decision making. Categorical representations of different types of expressions (e.g., facial, phonetic, emotional, and mental expressions) to distinguish between different conceptual and perceptual behaviors in the human brain have been widely studied in the literature. Categorization also plays a crucial rule in human cognitive development and is essential to several learning activities, including language acquisition, grammar learning, and speech perception.

Two types of categorization, namely perceptual (based on perceptual similarities between entities) and conceptual (based on the functions and interactions between entities), can be commonly defined in the human brain, even from the early stages of infancy (Berg-Cross 2006). Unlike perceptual categorization, which is more focused on the appearance of entities, the conceptual model is based on experience-driven patterns and needs a greater degree of maturity in the human's mental model. As stated by Harnad (1987), the basic categories are generated through ► categorical perception and specified through a learning process (► learning by acquaintance). In this way, one classifies the perceived objects (things) and then names them, e.g., man, horse, tree, small, big. Then new concepts can be learned through a set of descriptive information (e.g., logical expressions) based on the basic concepts and attributes, e.g., Centaur (man-horse) or Pony (small horse). ► Iconic representation and feature discrimination, which lead us toward categorical representation, contribute to learning by acquaintance, and ► symbolic representation, which uses category names as the atomic symbols, is used for descriptive learning (Harnad 1987). Together, categorical representation and iconic/symbolic representations (Harnad 1996) enable us to describe and model the real world in terms of categories and their members, their relationships, and their attributes.

A categorical representation of a domain can be performed by defining categories at different hierarchical levels, depending on the level of granularity, using different mediums such as Hierarchies, Sets, Lists, and so forth. In Artificial Intelligence (AI), ontologies are employed based on this ability of humans to find things familiar by using the categorizations in their brains. Ontologies, as hierarchical organizations of categories from general to specific, are meant to provide a semantic and conceptual basis for sharing knowledge about a domain of interest by defining concepts, properties, and axioms. In an educational sense, this conceptual model enables humans to apply their experiences of the past to similar future situations. For example, the experience of riding a bicycle can be applied to riding different bicycles with different brands, models, colors, and sizes. Since categories are highly dependent on a human's knowledge about the real world, they will evolve (be recategorized) as our knowledge increases.

Important Scientific Research and Open Questions

The idea of categorization is central to many disciplines in AI, machine learning, cognitive science, knowledge representation, and so on. Through technological advances, different formalisms and methods can be used to support categorical representations. An example is employing neural networks for iconic and categorical representations of different cognitive systems. In linguistics, the associations between labels (terminologies) and perceptual categories are considered key factors for language acquisition studies, perceptual learning, and developing "generative grammars."

Research on categorical representation has been faced with several challenging questions on the nature and semantics of categories and types of representations. Categories are derived based on different data sources (e.g., cognitive, behavioral, and environmental data). Categorization is defined in cognitive science as "the process of dividing the world into categories, and usually involves constructing concepts that provide mental representations of those categories" (Thagard and Toombs 2005), and can be done for both observable concepts (e.g., humans, limbs) and nonobservable concepts (e.g., genes, disease agents, a process such as injection). In the case of categorizations for nonobservables, the process also involves creating concepts for the unambiguous rationalization of the real world (Thagard and Toombs 2005). More formal categorization is also referred to as "any systematic differential interaction between an autonomous, adaptive sensorimotor system and its world" (Harnad 2005). In this definition, the term "systematic" has been used to exclude arbitrary interactions (e.g., the effects of the wind blowing on the sand) and an "autonomous, adaptive sensorimotor system" means a dynamic system that interacts and changes in time through adaptive changes in the states of the system. "Differential" implies that the categorization process generates a different kind of output from a different kind of input (Harnad 2005).

The categorical perspective in knowledge representation intends to express universal notions (truths). Category theory, with its universal grammar, provides an advanced abstract mathematical model that is used to represent and analyze the behavior of interacting objects within categories. The basic notations in category theory consist of a class of objects and a class of morphisms (relations between the objects), an identity and a composite morphism. The declarative approach offered by category theory represents and describes objects only in terms of their relationships and interactions with other objects, without the necessity of knowing about the internal structure of objects.

Cross-References

► Categorical Learning
► Categorical Learning in Pigeons
► Classification Learning
► Classification of Learning Objects
► Conceptual Clustering
► Explicit and Procedural-Learning Based Systems of Perceptual Category Learning
► Hierarchical-Network Model for Memory and Learning
► Knowledge Integration
► Knowledge Organization
► Knowledge Representation
► Mental Representations
► Ontology and Semantic Web
► Representation, Presentation and Conceptual Schemas
► Similarity Learning
► Vocabulary Learning
► Word Learning and Lexical Development Across the Lifespan

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Categorization

The ability to group objects or events according to a common attribute (or by category). In categorization, stimuli are grouped based on complex features, multimodal properties, or behavioral relevance. Sensory similarity alone does not necessarily place stimuli in the same category.

Cross-References

► Categorical Learning
► Categorical Representation

▶ Concept Learning
▶ Explicit and Procedural-Learning-Based Systems of Perceptual Category Learning
▶ Generalization Versus Discrimination

Categorization of Variation in Movement

▶ Impaired Multidimensional Motor Sequence Learning

Category Learning

▶ Categorical Learning
▶ Identification Learning
▶ Semantic Memory in Profound Amnesia

Catharsis Theory

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Synonyms

Purifying of the emotions; Release of emotional tension

Definition

A catharsis is an emotional release which is linked to a need to release unconscious conflicts. For example, rather than vent feelings inappropriately the individual may release these feelings through physical activity or another relieving activity.

Theoretical Background

Bergson (1911), among others, noted what might be an important aspect of pleasurable laughter, the need for detachment: "we do not laugh unless we are a bit detached." This notion can be viewed as part of a larger one, the possibility of a combination of involvement and detachment. In turn, this idea can be part of an elaborated theory of catharsis that has never been tested.

Aristotle originated a theory of catharsis in the theater.

> ▶ The function of tragedy is to accomplish a clarification (or illumination) through catharsis of pity and fear. (Nussbaum's translation 1986, p. 391)

The idea of catharsis is currently in disrepute because Freud rejected it, even though his first book reported its success (1895). Experimental psychologists also think they have disproved it, because they have shown that *acting out* anger usually does not get rid of it. Currently it is the fashion to refer to catharsis as a simplistic hydraulic theory, as if there were only one theory rather than many (Scheff 1979, 2007).

However, Aristotle did not propose that audiences shout in anger or run away in fear. He was referring to the effect of simply watching a tragedy, just as Wordsworth wrote that poetry is emotion recollected in tranquility.

The crucial thing, according to theories of *esthetic distance*, is that although the audience identifies with the players, and feels their emotions, at the same time realizes that they are safe in the theater (Goddard 1951; Evans 1960). At this distance, moving rapidly in and out of their own feelings, emotions that might be painful if one was completely lost in them become pleasurable. This movement provides a feeling of control: if the pain gets too great, one can stop. In a tragedy, one can have a "good" rather than a bad cry, and experience good fear rather than the painful kind.

Phrased slightly differently, theater must generate emotions in the audience, but not to the point of getting lost in them (*underdistanced*). If it does not generate emotions, it is *overdistanced*. The third way is being *both* emotionally involved and detached at the same time, esthetic distance. The audience is to identify with the characters to the point of feeling their emotions, but at the same time remembering that they are *not* the characters.

The idea that we may experience ourselves from a distance is a key feature in the social psychology of Cooley and Mead. In their approaches, the self is constituted by a distancing process. Cooley pointed to what he called the *looking glass self* (1922), an accepted part of modern sociology. As he put it: "We live in the minds of others without knowing it." The last two lines became particularly important because Mead and his followers did not follow them up, as indicated below. Cooley was referring to the reflexive self-consciousness of our experience, how we continually monitor our self from the point of view of others.

G. H. Mead developed Cooley's idea in a different way. He called it "taking the role of the other." Mead pointed out that ordinary discourse is so ambiguous that we must be constantly moving in and out of the mind of the other person, guessing at the meaning of their discourse by seeing it not only from our own point of view, but also from theirs. Unlike Cooley, Mead and his followers failed to note how unconscious this process becomes. And neither Cooley nor Mead realized the relevance of their work to the distancing of emotions.

My students experience roller coasters as pleasurable, but only if they are sure that the ride is safe. They allow themselves to feel fear because they are able, at the same time, to feel safe, rather than becoming completely caught up. Levine (1997) refers to this process as pendulating, moving very rapidly in and out of emotions that would otherwise be painful. We move so fast that we usually do not realize it. These states can occur not only in the theater but whenever we feel safe enough to replay intense emotional experiences, such as describing them to another person we trust, or, occasionally, reliving them alone.

Important Scientific Research and Open Questions

Aristotle linked catharsis to clarification or illumination, but he did not explain the connection. In which way does catharsis lead to these desirable outcomes? In order to understand what is taking place in catharsis, emotions need to be defined. John Dewey (1894/1895) proposed that felt emotions are certain bodily preparations to act that have been delayed. Since Dewey's article dealt only with emotions in general, and not specific emotions, it had very little influence. It becomes relevant only if we apply it to specific emotions, like grief or shame, anger or fear. These emotions occur when the body is mobilized to act in certain ways, states of bodily arousal in order to complete certain acts. What are these acts, and how can they be completed?

For purpose of discussion, suppose that grief involves bodily preparation to cry. Sobbing with tears would require, at the least, muscular contractions in order to sob, activation of the tear glands, and some adrenaline to energize these preparations. The more rapidly these preparations are carried through, the less feeling of sadness. If one cried copiously and instantly, little sadness would be experienced. Sadness requires delay, just as sexual pleasure can be heightened by foreplay. Crying, under certain conditions discussed below, might be the orgasm for grief.

Embarrassment/shame provides another example. When my students tell the class their most embarrassing moment, many of them are convulsed with laughter telling the story. Laughter seems to be the orgasm of shame. However, it is often difficult to attain enough distance, especially if one was deeply humiliated. Many repetitions of just talk about the incident may be needed before one can find humor in it.

It also needs to be said that just as there is a good cry and a bad one, there is also a good laugh and a bad one. A good laugh turns out to be when one is laughing at one's self ("silly me") or the universe, but not at other people. Laughing at others, as Billig has pointed out (2005), usually is ridicule, driven by anger: no help to either party. There is also faked laughing, which does not engage any part of the cathartic system, but is more like a voluntary speech act.

Esthetic distance is experiencing strong emotions in a safe environment: theater, film, books, songs, or telling one's experience to an empathic person, or even to one's self. I once had an intense fear experience in this mode. After an excruciatingly dangerous moment, when I was safe, I realized that I was still tensed up because of the danger I had encountered. Not knowing what to do, I began repeating the phrase "I am afraid." After many repetitions my body took over, shaking and sweating till my clothes were drenched. It was not painful, and I felt completely relaxed when it was over. Perhaps it was the nearest that I ever came to an illumination. Shaking and sweating would seem to signal the catharsis of fear.

Like many people, when angry I may lash out. But I have had several anger experiences of a quite different kind. I told the culprit "I am angry at you because. . . . ." in an ordinary voice. Since this approach is so undramatic, I have had to repeat my complaint several times. Then two things happened: the other person started apologizing, and I felt hot. I realized that it was not the room that had gotten warm, but my body. Catharsis in this case does not involve the acting out of anger, the mistake of the systematic studies of anger "catharsis." It is rather an internal process: heat seems to metabolize the adrenaline for bodily preparation to fight. Body heat signals the internal orgasm of anger.

These comments on catharsis were brief. For further discussion, see my book (1979), article, Catharsis and Other Heresies (2007), or my video on emotions, backed up by two Swedish rock stars (Scheff 2009).

Cross-References

- ► Aristotle (384 BC–322 BC)
- ► Aristotle on Pleasure and Learning
- ► Dewey, John
- ► Psychodynamics of Team Learning

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Causal Attribution

► Attribution Theory of Motivation

Causal Induction

► Causal Learning

Causal Inference

► Causal Learning
► Human Causal Learning

Causal Learning

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Synonyms

Causal induction; Causal inference; Causal reasoning; Contingency learning

Definition

Learning the cause–effect relationships or determining the causal status among a set of two or more events. Learning causal relationships can be characterized as a bottom-up process whereby events that share contingencies become causally related, and/or a top-down process whereby cause–effect relationships may be inferred from observation and empirically tested for its accuracy.

Theoretical Background

Causal learning has its roots in philosophy. Aristotle proposed four causes: material (what something is made of), formal (i.e., structural, how something is made, its structure and form), efficient (or moving; necessary for the effect's existence), and final (i.e., functional, the purpose, an egg is the cause of a chicken). The British Empiricists (Hume, Lock, J. S. Mill, et al.) suggested that cause–effect relationships cannot be observed, but are merely inferred through statistical regularities between events, often captured in associative properties (see e.g., Hume 1739). Nativists, such as Kant (1781), argued that the human mind has a priori knowledge of the construct of causality. The concept of causation is applied to our knowledge (both a priori and acquired through experience) to allow us to label events as causal when they appear so to us.

Investigation of causal learning in psychology follows from these philosophical roots. Treatment of concepts involving causal learning and induction fall into three groups: Perception, Associative learning, and Reasoning.

Belgian psychologist Albert Michotte argued that causality is determined directly through perception. He demonstrated this by describing our perception of causality in how billiard balls move and interact on a billiard table. When one billiard ball strikes a second, the first ball transfers its motion to the second. Michotte (1963) referred to this perception of transfer of movement from one colliding object to the next as "ampliation of the movement," what is now generically referred to as the "launching effect." This gestalt approach treats causal knowledge as being derived directly from perception rather than acquired through experience of contingency relations between causally connected events. Thus, Michotte's framework – which still dominates the field of causal perception – shares more with Kant's nativist framework than with Hume's empiricism.

The associative learning approach to causal learning is a direct descendent of the associationist philosophy of David Hume. Proponents of an associative learning approach to causal learning and induction argue that the laws of associative learning, such as contiguity, contingency, and temporal priority, provide a sufficient account for how humans and other animals acquire understanding of cause–effect relationships. Pavlovian conditioning involves pairing an antecedent event (called a conditioned stimulus or CS) with a subsequent, usually motivating, event (called the unconditioned stimulus or US), thereby establishing a CS–US association. The CS–US association may be represented causally, with the CS as the cause of the US. Instrumental learning, in which changes in behavior are driven by their consequences, may also serve as a model of causal learning. This case is particularly strong for goal-directed learned behavior in which the action is made as if to produce the goal (for appetitive or desirable outcomes) or prevent the goal from happening (for aversive or undesirable outcomes) (Dickinson 2001). In this framework, instrumental actions are suggested to be mediated by causal knowledge. Much of the work to support this framework comes from research investigating the parallels between associative learning phenomena in nonhuman animals and similar phenomena in human contingency learning experiments. The degree to which effects in human contingency learning mirror those found in animal conditioning experiments establishes the latter as a model for the former. This approach has been largely successful in establishing a connection between these two research paradigms, and few would dispute that this similarity is meaningful. Where the debate centers is on the interpretation of this similarity between animal conditioning experiments and human contingency learning experiments. Proponents of the associationist approach argue that the similarity reflects the role of the simple, algorithmic-level learning mechanisms of Pavlovian and instrumental conditioning in causal learning in both nonhuman animals and humans. An alternative perspective is that the similarities between these two research paradigms reflect the operations of rational top-down psychological principles of causal reasoning and induction at least in humans and perhaps in nonhuman animals as well.

An alternative theoretical approach to causal learning and reasoning involves the application of rational statistical models (also called normative or functional models) to human causality. This approach has also been extended to work with nonhuman animals in recent years (Penn and Povinelli 2007). According to the normative approach, causal knowledge is acquired by computing the covariation between candidate causes and effects. The delta-p model is one popular generic form of the computation rule for the contingency between cause and effect (see Fig. 1; after Allan 1980). The indicated conditional probabilities can be pieced together into a causal model. A causal model is a representation containing both a structural framework consisting of links between causes and effects, and the strength of the relationship of each link, also referred to as causal power (Cheng 1997). Rational models typically focus on delineating the rules that govern causal structure learning or how causal power is computed. An implicit assumption in these models is that causal relationships reflect either a force that

	Effect	No Effect
Cause	a	b
No Cause	c	d

Δp = p(effect/cause) – p(effect/no cause)

Causal Learning. Fig. 1 2×2 contingency table showing relationships between Cause (present = cells a and b; or absent = cells c and d) and Effect (present = cells a and c; or absent = cells b and d). At the bottom of the figure is the equation for calculating delta p, the change in judged contingency between cause and effect. This equation takes into account the difference between the probability of the effect given the presence of the cause (cells a and b) and the probability of the effect given the absence of the cause (cells c and d)

allows a cause to generate or prevent its effects, or a physical mechanism that ties effects to their causes – though these forces or mechanisms are rarely specified in descriptions or parameters of the models. While there has been a tension in the literature on whether associative or rational models provide better theoretical tools to investigate causal learning, a consensus view has recently emerged that the two classes of models are more complementary than exclusionary and they reside at different levels of analysis as characterized by Marr (1982). Associative models are thought to operate at the algorithmic level of explanation (though most associative models, such as the Rescorla-Wagner, 1972, model are presented in computational form), while rational models reside at the computational level of analysis.

There has been a recent extension of rational models that focuses on the role of agency in causal learning and judgments. The basic premise is that an agent can manipulate, or observe another's manipulation of, an outcome. This manipulation is termed an intervention and can directly affect that event's causal status. If intervening on the event results in changes in other events (e.g., watering the lawn results in green grass), then the manipulated event is deemed a cause of the other, resulting events. Manipulations can include turning a dichotomous event on or off (e.g., flicking a light switch), increasing or decreasing a continuous event's value (e.g., turning up or down a thermostat setting), or increasing or decreasing the likelihood of a probabilistic event (e.g., smiling or frowning when asking someone for a date). Knowledge derived from interventions, often characterized as a top-down process, can be contrasted with the bottom-up processes of deriving knowledge from observations in the absence of intervention (e.g., via associative learning). Evidence suggests that causal induction from interventions develops early in human development, and may be lacking in nonhuman species, though the comparative question is only beginning to receive attention. Interventions may be effective in judging causal relationships because they permit the generation of many cell b and cell d events (see Fig. 1).

Important Scientific Research and Open Questions

While a consensus is starting to emerge regarding the complementary roles of bottom-up (e.g., associative) and top-down (e.g., rational) models of causal learning and induction, this is by no means a ubiquitous view (Shanks et al. 1996). One or the other approach may yet win out favor over the other. In fact, rational (propositional) processes have recently been proposed as an alternative account for bottom-up associative processes. Nevertheless, the nature of the relationship between associative and rational accounts is still an open question. Another important area of future inquiry concerns brain–behavior relationships in causal learning and inference. Imaging methods are starting to identify neural structures active during causal inference in humans. But more experimental approaches that dissect the contribution of neural systems to causal processes are still needed to move beyond hypothesis generation and into establishing the brains mechanistic role in causal learning and inference.

Cross-References

► Animal Learning and Intelligence
► Associative Learning
► Bottom-up- and Top-down Learning
► Bounded Rationality and Learning
► Contingency in Learning
► Human Causal Learning

▶ Human Contingency Learning
▶ Inductive Reasoning
▶ Inferential Learning and Reasoning
▶ Normative Reasoning and Learning
▶ Pavlovian Conditioning
▶ Psychology of Learning (Overview Entry)
▶ Role of Prior Knowledge in Learning Processes

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Causal Learning and Illusions of Control

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Synonyms

Contingency learning; Illusions of causality; Superstitious behavior

Definition

▶ Causal learning is the process by which people and animals gradually learn to predict the most probable effect for a given cause and to attribute the most probable cause for the events in their environment. Learning causal relationships between the events in our environment and between our own behavior and those events is critical for survival. From learning what causes fire (so that we could either produce or prevent the occurrence of fire at will) to learning what causes rain, what causes cancer, or what caused that particular silly accident that we had with the car a few days ago, both the history of humankind and our individual history are full of examples in which causal learning is crucial. But, as can be said for other forms of learning as well, causal learning is not free of errors. Systematic biases and errors are known to occur under certain conditions. One of such common biases is the illusion of control. *The illusion of control can be defined as the belief that one's behavior is the cause of a desired event that is actually independent of it.* Illusions of control are an important factor in the development of superstitions. For instance, the superstitious belief that by dancing one can produce rain, is normally accompanied by the illusion of controlling rain.

Theoretical Background

The origins of research on causal learning can be traced back to the Greek philosopher Aristotle and it has ever since interested philosophers, experimental psychologists, cognitive scientists and, in general, all scientists interested in how humans learn and acquire knowledge. Nowadays, causal learning is generally studied in the experimental psychology tradition and is normally considered to be a central aspect of cognition. However, as it is the confluence of causal learning and the illusion of control research what we are addressing in this entry, it is interesting to note that this general cognitive perspective has not been applied to the study of the illusion of control until very recently. The illusion of control has traditionally been regarded as one of those cases in which the cognitive system fails to work in an adaptive manner. As such, the study of the illusion of control has been more often linked to Clinical, Health, and Social Psychology than to the Cognitive and Learning Sciences. Today, however, the study of the illusion of control is recovering its place as part of the Learning Sciences and is being regarded as the normal consequence of the way the learning system works.

In a typical laboratory experiment on the illusion of control, a given outcome (e.g., getting points in a computer game) is programmed to occur at certain intervals, or according to a predetermined sequence, and the experimental participants are instructed to try to obtain it. The usual result is that, when asked at the end of the experiment about the extent to which they believe to have controlled the outcome, participants normally believe their control to be significantly greater than the value of zero which has been programmed by the experimenter (e.g., Alloy and Abramson 1979). The current use of ► web-based control for experiments on human learning allows demonstrating that these effects occur not only in the laboratory but also in the more noisy and uncontrolled arena of the Internet. This suggests that the illusion of control is a robust phenomenon that develops easily in natural settings.

Ever since the seminal laboratory studies on the illusion of control, Ellen Langer (1975) showed that the personal implication of the participant was an important factor in producing the illusion. Therefore, a traditional interpretation has been that emotional and motivational factors, such as a need for control and a need to protect self-esteem, were at the basis of the effect. Moreover, an association between the illusion of control and an absence of depression has been repeatedly reported, which has also lead to the suggestion that either the illusion protects from depression, or depression protects from the illusion (Alloy and Abramson 1979; Taylor and Brown 1988). In line with this, the illusion of control has been described as the inverse of the learned ► helplessness effect that occurs when people realize that desired events are uncontrollable (e.g., Langer 1975; Matute 1996). These findings have also been taken sometimes as supportive of the motivational, self-esteem explanation, though, as we will see, they do not necessarily support this view over the learning approach.

Even though it seems clear that the illusion of control can provide beneficial effects on self-esteem as well as a protection from depression and helplessness, these prophylactic effects, however comfortable they may feel, do not provide an explanation for the illusion. This is so because, in the first place, protection of self-esteem could well be a side effect of the illusion rather than its cause. Secondly, and most important, because the self-esteem hypothesis does not attempt to explain how our cognitive system produces the illusion: it simply postpones the question. Being the illusion of control the product of a learning system (and more specifically, a particular case of causal learning), general learning theories that can account for causal learning can in principle be applied to the illusion of control as well. These include theories of ► associative learning, ► connectionist learning, ► Bayesian learning, or ► inferential learning. Despite their differential proposals, what is common to all these learning theories is that all of them would assume that the illusion of control is the outcome of a much more general cognitive mechanism. Many theories that explain causal learning as the formation of associations between causes and effects, or as statistical reasoning or even as an inferential process, would agree to predict an illusion of control when both the candidate cause and the to-be-explained effect occur frequently and do coincide frequently by chance. Not surprisingly, these are the conditions where the illusion of control is most often observed.

An important additional prediction of the learning approach is that, if the illusion is the result of a normal process of causal learning, then it should occur regardless of whether the potential cause is the participant's own behavior or an external cause. This is not what the Social and Clinical Psychology theories of the illusion would predict. According to these latter views, the illusion occurs to protect self-esteem and whenever the potential cause is external there is no need to protect self-esteem. The amount of evidence in the area of learning that shows that causal illusions occur when the potential cause is an external event suggests that personal involvement is not needed to produce these illusions. Personal and motivational factors could perhaps enhance the illusions, but they are not necessary. Both the illusion *of causality* that occurs when the potential cause is external and the illusion *of control* that occurs when the potential cause is the participant's behavior are enhanced under the same conditions that are predicted to be critical by the many theories of causal learning. Indeed, many ► machine learning algorithms designed to learn according to the theories of natural learning will necessarily suffer illusions of causality (and of control) when exposed to those conditions. Such conditions are many, but perhaps the most relevant can be summarized as follows: (a) a high frequency of occurrence of a desired uncontrollable outcome (or a low frequency when the outcome is aversive); (b) a high frequency of the potential cause (i.e., our own behavior when we speak of an illusion of control; any other cause when we speak, more generally, of an illusion of causality); and (c) a high number of coincidences of the potential cause and the outcome (Alloy and Abramson 1979; Matute 1996; Matute et al. 2010). It is interesting to note that the high frequency of the potential cause is equivalent with a high personal involvement when the potential cause is the participant's behavior. It is possibly for this reason that many of those results have often seemed to support the self-esteem explanation.

Important Scientific Research and Open Questions

One of the challenges related to this topic is to find out what the role of personal involvement really is. Does it really increase the illusion? If so, why? How? Is it because our perceptual and learning abilities are modified when we evaluate the efficacy of our own behavior? Could it be that we learn causal relationships in the same way regardless of whether it is our own behavior or an external cause what plays the role of the cue, but that we then make a different judgment as a function of whether the potential cause is our own behavior? Many questions related to these ones are becoming really exciting topics of debate right now. The perception of action, of will, of authorship... How do we attribute a given outcome to our own behavior or to other sources? How do we decide that we are responsible for a certain action? Does this depend on the consequences of the action? These and other related questions concentrate a great deal of the research being conducted at present (and possibly in the following years) on the illusions and perceptions of causality and of personal control.

Another important issue is whether these effects are adaptive and should be promoted, or, by contrast, should be regarded as maladaptive effects to be "corrected" in therapy. This question can be understood in various ways. If we look at the evolution of our species, we must admit that if superstitions and illusions of control have survived up to our days, this necessarily must mean either that they are adaptive on their own right or that they are an innocuous collateral effect of an otherwise adaptive learning process. A possible consequence of the normal functioning of the learning system could be that those potential causes and effects that occur together and become linked during causal learning will, from time to time, turn out to be causally unrelated. This would be a collateral effect of the causal learning system working in a way which will most often be adaptive and correct, but sometimes vulnerable (Matute 1996). In consequence, as we already noted, many artificial and machine learning algorithms that model learning according to the predictions of current theories of ► human causal learning do also suffer the illusion. This does not mean that the algorithms are programmed to do so. However, the illusion is a consequence of their causal learning dynamics. As of natural selection, a system that detects causal relations that sometimes result illusory might be more adaptive than an alternative system with such a high threshold for the detection of causal relations that often fails to detect relations that do exist (e.g., McKay and Dennett 2009).

In addition, the illusion of control itself could be adaptive on its own (Langer 1975; Matute 1996; McKay and Dennett 2009; Taylor and Brown 1988). If the illusion makes us remain active in our trying to obtain desired events, such as rain or fire or health, then, whenever we are uncertain about whether a relationship is really causal, it should be adaptive to maintain the illusion that our behavior is being useful so that we persist in trying to obtain the desired outcome. As a source for behavioral persistence, the illusion of control could be at the basis of human change and adaptation. The alternative option, which would consist in realizing that there is no control over important outcomes and that therefore it makes no sense to keep on trying, would produce ► helplessness, which includes behavioral cessation in addition to depression and other problems. In this sense, it appears that maintaining a high level of activity is possibly an adaptive strategy. Sometimes, however, ceasing dancing for rain, and even going through a transient depression after realizing that we cannot cause rain, can be adaptive too. It could cause our efforts to be redirected so that we can discover better ways to bring water to our land. As we already noted somewhere else (Matute et al. 2010), applying what we know about the illusion of control to reduce the impact of superstition in our society should contribute to a better world. In one way or another, there must be an optimal level of the illusion of control (not too low, not too high) which enhances persistence while still allowing room for change.

Cross-References

► Associative Learning
► Bayesian Learning
► Causal Learning
► Connectionist Theories of Learning
► Human Causal Learning
► Inferential Learning and Reasoning
► Learned Helplessness
► Machine Learning
► Web-Based Control for Experiments on Human Learning

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Causal Perception

► Human Causal Learning

Causal Reasoning

► Causal Learning

Causation of Behavior

► Attribution Theory of Motivation

Cause-Effect Learning Versus Effect-Cause Learning

► Predictive Versus Diagnostic Causal Learning

CBL

► Case-Based Learning

Central Bottleneck

► Capacity Limitations of Memory and Learning

CER - Conditioned Emotional Response

► Conditioned Suppression

Chameleon Effect

► Mimicry in Social Interaction: Its Effect on Learning

Change in Behavior

► Inhibition and Learning

Change in Learning Organizations

► Organizational Change and Learning

Change of Concepts

► Conceptual Change

Change of Values Through Learning in Organizations

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Synonyms

Value learning

Definition

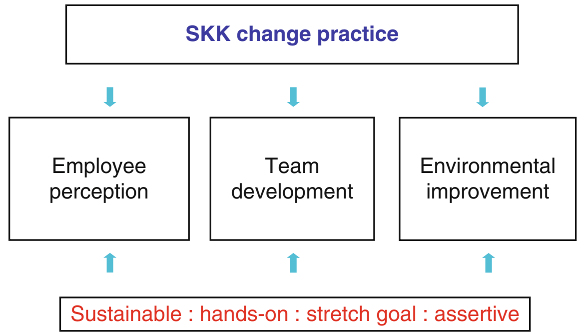
According to Robbins and Judge (2010) values represent basic convictions that "a specific mode of conduct or end-state of existence is personally or socially preferable to an opposite or converse mode of conduct or end-state of existence." Values lay the foundation for our understanding of people's attitudes and motivation and influence our perceptions and behavior. Hence, it can be said that one's values are determined by one's belief and one's values determine one's attitudes which at the end determine one's behavior.

Theoretical Background

In the study Implementing Change Practice through Learning and Development: A Case Study of Kaeng Khoi Cement Plant (SKK), Siam Cement Group, Thailand (Utsahajit 2009), the company begins its change primarily because of external pressure. As the business competition becomes more severe and a few international big players in cement industry have shown their interest in expanding their current business and investing new businesses in Thailand, the Siam Cement Group has decided to commit in an extensive change practice to level up their organizational performance.

Change practice can be grouped into three categories (as shown in Fig. 1), namely, Employee Perception, Team Development, and Environmental Improvement.

Employee Perception activities focus on aligning employees' perception toward changes in organization. The activities devote to continuously learning together through hands-on experience, both mentally and physically, creating the readiness for change in employees by promoting the attitude of accepting changes as challenges and pathways to success in three levels: customer, community, and corporate. Moreover, employees are encouraged to believe in three critical values: commitment, consistency, and communication. A learning camp which incorporates the concept of constructionism is implemented. Constructionism is defined by the organization as a learning method where learners determine what they want to learn and how they want to go about it. Learners create new knowledge by building on to their old or current knowledge. They reflect and share. They learn the content but, most importantly, they learn how to learn. Moreover, the company implements a team-learning activity where learners are grouped to work on selected projects under the guidance of facilitators.



Change of Values Through Learning in Organizations. Fig. 1 Change activities and core values

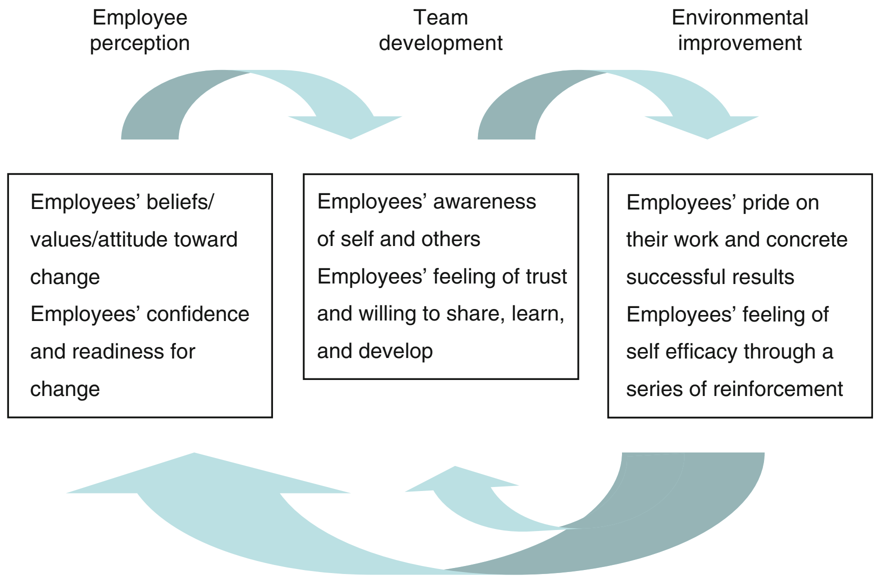
Team Development activities focus on creating a sense of excellence, trust, and collaboration among employees. The organization strongly believes changes become successful challenges when employees embrace excellent quality, communicate truthfully among one another, and are willing to do everything possible to achieve mutual goals. Team Building is one example of Team Development activities where both indoor and outdoor learning activities are effectively implemented.

Environmental Improvement activities focus on bringing changes into solid, visualized evidence. The activities entail improvement both in terms of physical environment and of work atmosphere.

Additionally, change practice cannot be made successful without well-designed support strategies. Goodstein and Burke (2000) suggested methods of implementing a change include individual change strategy (e.g., setting up a comprehensive training program), technostructural strategy (e.g., modifying the structure, individuals' jobs, and/or work procedures), data-based strategy (e.g., conducting a companywide survey to assess organizational culture for the purpose of using the data to pinpoint required changes), and organization development strategy (e.g., collecting information from organizational members about their views regarding what needs to be changed and acting accordingly). All of these strategies are evident in the change practice at Kaeng Khoi Cement Plant. For individual change strategy, the company develops a comprehensive learning and development scheme using various activities. For technostructural strategy, the company restructures the organizational hierarchy to be flatter and less centralized. For data-based strategy, the company deploys the organization-wide communication campaign and provides various communication channels for information to flow upwardly, downwardly, and laterally. Finally, for organization development strategy, the company undergoes many activities to ensure the involvement of people in voicing their opinions and valuable ideas regarding change practice.

Change practice at Kang Khoi Cement Plant is a planned program involving the whole system and relying on many experience-based learning activities, and the focus is on group behavior and team development. The company believes that before change can take place people in the organization have to first perceive change. Their value and attitude toward change must be positive and they must recognize that change is good, essential and attainable, first and foremost. Then when they are open to change and feel ready, people can be put into work group and team building process can begin. They are, therefore, in a stage of readiness to learn and develop. People behave and act with trust. They feel comfortable admitting their ignorance, reflecting and sharing their knowledge and feeling. Finally, the third component of the change practice can be realized. Improvements are then felt and seen around the plant. Figure 2 shows how employees' behaviors develop.

From Fig. 2, as employees' perceptions toward change become appropriate and healthy, they feel more confident and ready for change. Then they are developed individually and collectively through a series of team-learning activities. They become aware of themselves and others, trust other group members, and willing to share with and learn from one another. Finally project-based activities are assigned to the employees at the right time. Successful results are obtained and each team member feels good about the outcomes. This, in return, solidifies the right attitude of employees toward change, increases their confidence and readiness for change, raises the awareness of the importance of working in teams to achieve the ultimate goal, and promotes a trusting learning atmosphere.



Change of Values Through Learning in Organizations. Fig. 2 Employees' behavioral transition

Important Scientific Research and Open Questions

Learning is at the heart of Kaeng Khoi Cement Plant's change practice. The Plant has made learning become a way of life in their systems. Whether an organization adopts a formal and systematic approach, or is committed to the ongoing and long-term process of individual growth and development via a systematic approach, learning is the essential precondition for any change in performance at work (Megginson et al. 1999). When learning is based on and follows from experience, it is obvious that learning will be influenced by a person's exposures to different situation. Learning outcomes leading to increased capabilities will, therefore, reflect the nature, variability, and intensity of what people are required to do and the opportunities to experience new and different situations. Learning through variety of activities at Kaeng Khoi Cement Plant provides employees with the ability of how to learn and how to apply what they learn to actual situations.

Learning provides employees the right tool for dealing with changes in the organization. Only learning can keep up with change. Learning at or for work facilitates the required behavioral change. It creates, adapts, enlarges, and deepens knowledge. Without new knowledge or adapted knowledge, it is not possible to change. People become competent and able to meet the demands of change through learning. They look at change as challenging and achievable when they feel comfortable and are equipped with knowledge and learning to learn skills.

In the book titled Practical Buddhism: The Legacy of Buddhadasa Bhikkhu (2006), Buddhadasa Bhikkhu used the term "learning inside" to refer to the true learning that aimed to look into oneself to understand the true meaning of life and the noble truth in order to form the right set of belief about one's life. The right set of belief then determines one's values and directs one's behavior. Only true learning will bring about appropriate and sustainable change.

Cross-References

► Action Learning
► Active Learning
► Behavioral Modification, Behavior Therapy, Applied Behavior Analysis and Learning
► Learning to Learn
► Lifelong and Worklife Learning
► Metacognition and Learning
► Transfer of Learning
► Values and Lifelong Learning
► Workplace Learning

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Changeability

► Flexibility in Problem Solving: Analysis and Improvement

Changed Conditions for Learning

► Socio-technological Change of Learning Conditions

Changing Mental Models

► Learning-Dependent Progression of Mental Models

Chaotic Dynamics

► Multiagent Q-Learning Dynamics

Character

▶ Personality Effects on Learning

Character Education

A theory of prosocial development focused on the teaching of virtue through modeling, direct instruction, and practice.

Cross-References

▶ Moral Learning
▶ Video Games for Prosocial Learning

Child Development

▶ Infant Learning and Development

Child-Centered Teaching

▶ Learner-Centered Teaching

Children's Critical Assessment of the Reliability of Others

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Synonyms

Credibility judgments; Evaluation of testimony; Selective trust; Skepticism

Definition

Children's critical assessment of the reliability of others refers to the ability of children to evaluate the extent to which specific individuals are reliable sources of information. It involves reasoning about individual differences in the knowledge and motives of potential informants, and using this information to assess an informant's credibility and act upon the information that is learned.

Theoretical Background

The capacity to obtain knowledge from others, rather than exclusively relying upon what is observed or experienced directly, offers important opportunities for learning. This capacity has long been recognized in developmental psychology and has been a major focus of ▶ sociocultural theory. For decades, cognitive developmental psychologists have searched for the earliest evidence of children's ability to make use of information they obtain from others. Research in this area has shown that by age 1, children are capable of using the emotional responses of caregivers to guide their judgments about which objects or people are to be avoided.

More recently, there has been greater interest in what happens in the years following infancy. During this time, children's language production and comprehension skills improve, giving them increased opportunities to learn from others, and they begin to develop cognitive skills that allow them to evaluate what they have learned more effectively. A central assumption of this research is that because information that is obtained from others is not always accurate, it is important for children to critically assess what others tell them, and that without such an ability they are vulnerable to being misinformed and manipulated.

The primary focus of recent work in this area concerns how children evaluate the credibility of specific informants. Much of this work has involved showing children pairs of potential informants who differ on a key dimension, and measuring which informant children prefer. A standard paradigm involves a training phase in which young children are presented with familiar objects such as a ball and a cup, and then observe one informant providing accurate names for the objects and another informant providing inaccurate names. Then, during a test phase, the two informants identify a series of novel objects using different novel labels such as "mido" and "loma." Participants are asked which name is most likely to be accurate and which informant would be most likely to provide accurate information in the future. Results indicate that 3–4-year-olds consider informants with a history of being accurate to be more reliable than those with a history of being inaccurate (Harris 2007).

Important Scientific Research and Open Questions

One reason researchers have sought to determine how children learn to think critically about the reliability of others is that this understanding is thought to be closely linked to developing conceptions of mental life. Recent research has provided evidence of such an association, including direct links between source evaluation and tests of mental state understanding (Vanderbilt et al. in press). Further evidence comes from demonstrations that before children reach age 5, they are sensitive to a wide range of cues that can serve as indicators of an informant's knowledge. For example, they consider the extent to which informants have access to relevant information, and expect individuals who create objects to be more reliable informants about the objects than are other individuals (see Heyman 2008).

By age 4, children have some understanding that people are not always motivated to convey what they know accurately. However, this does not mean that they are generally successful at recognizing and acting upon such motives. For example, 4-year-olds will often accept and act upon the advice of individuals who they have repeatedly observed trying to deceive others (Vanderbilt et al. in press). Even 6-year-olds have difficulty anticipating the potential effects of motives that relate to social desirability (Heyman 2008), and understanding the ways in which judgments can be biased due to personal relationships (Mills and Keil 2008).

There has been considerable interest in the effectiveness of children's efforts to seek out information from others. This work has shown that when children as young as age 4 are actively seeking explanations they are often able to evaluate the adequacy of the responses they obtain, and may repeat their questions or devise their own explanations if the answers they receive are not satisfactory (Frazier et al. 2009). However, children of this age often have substantial difficulty with generating effective questions.

Another emerging research area concerns children's use of information obtained from others to construct more elaborated systems of beliefs, including those relating to scientific or supernatural explanations of the natural world. Findings suggest that children are capable of applying different systems of beliefs to different contexts, and that they often make creative attempts to merge different frameworks of beliefs in an effort to main coherence and consistency. For example, Legare and Gelman (2008) found that South African children often explained AIDS in ways that integrated their beliefs about witchcraft with scientific explanations about the nature of the disease.

It will be important for future researchers to investigate how children think critically about the information they obtain from others in real-world contexts that have significant implications for their well-being, such as when deciding whether to disclose personal information to individuals they meet online. Another key area for future research is to understand how children's ability and willingness to engage in critical thinking is influenced by their desires and emotions. Finally, more research is needed concerning the types of experiences that foster critical thinking most effectively. This work should lead to insights into how to help children maximize the benefits of learning from others, while minimizing the risks.

Cross-References

► Belief Formation
► Collaborative Learning and Critical Thinking
► Scaffolding Learning
► Social-Cognitive Influences on Learning
► Socio-Cultural Learning
► Vygotsky's Philosophy of Learning

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Children's Learning from Television

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Synonyms

Educational television; Education-entertainment; Infotainment; Instructional television

Definition

Educational television refers to television programming that is intended to promote children's learning of academic and/or prosocial content, either in or outside the classroom. Alternate labels for such programming include *instructional television*, *curriculum-based programming*, *educational/informational programming*, *infotainment*, *edutainment*, and *entertainment-education*. Often, the alternate terms are used to connote somewhat different classes of television programming; for example, *instructional television* often refers to television programs produced for school use, whereas *infotainment* carries the connotation of "lite" educational content for consumption on broadcast television.

Theoretical Background

Several theoretical approaches have been proposed to explain aspects of children's interaction with educational television and its effects. These include models to describe cognitive mechanisms that underlie comprehension, children's acquisition of social behavior, and the long-term impact of educational television.

Comprehension. Growing out of a tradition in information processing theory and cognitive psychology, Fisch's (2004) *capacity model* views television programs as complex audiovisual stimuli that require viewers to integrate a range of visual and auditory information in real time. Educational television programs pose even greater processing demands, because these programs typically present narrative (i.e., story) content and educational content simultaneously, so that the two must compete for the limited resources available in working memory. Thus, the model predicts that comprehension of educational content will be stronger, not only when the resource demands for processing the educational content are low, but when the resource demands for processing the narrative content are low as well.

In addition, the model argues that comprehension is affected by *distance* – the degree to which the educational content is tangential to the narrative (in which case, the two must compete for working memory resources) or integral to it (in which case, the two complement each other, so competition is reduced). Comprehension of educational content typically would be stronger when the educational content is integral to the narrative than when it is tangential to it.

Social behavior. Theories regarding television's influence on children's social behavior often have concerned the effects of television violence on children's aggressive behavior, but many of these models are equally applicable to prosocial behavior – and, indeed, to social behavior outside the context of television as well. Various mechanisms have been proposed to account for such learning, such as acquiring new behaviors via observation and imitation of live models, or influencing the selection of behaviors from children's existing repertoires of behavior.

A point of intersection among all of these theoretical approaches may lie in Bandura's (1986) *social cognitive theory*, in which the path from watching television to viewers' behavior proceeds through four discrete stages, each of which is subject to its own influences: (1) attentional processes that determine what is selectively observed by the viewer (due to, e.g., salience or viewer preferences), (2) retention processes through which modeled information is represented in memory in symbolic form, (3) production processes in which the viewer translates stored abstract representations into actions, and (4) motivational processes, which can determine whether learned behaviors will be performed, depending upon their functional value or potential risk in a given situation. Thus, for a child to imitate cooperative behavior from television, the child would have to attend to the character's behavior, create and store a schematic representation of the behavior (or activate a preexisting analogous schema in memory), subsequently translate that schematic representation into physical action when faced with an appropriate situation, and be motivated to do so. Failure at any of these stages could result in the viewer not displaying the behavior in a real-life situation or laboratory assessment.

Long-term effects. Huston et al.'s (2001) *early learning model* focuses on the long-term effects of educational media, and how such media might interact with all of the other influences in children's lives. Under this model, three facets of early development are proposed as pathways by which long-term effects can result: (1) learning preacademic skills, particularly related to language and literacy, (2) developing motivation and interest, and (3) acquiring behavioral patterns of attentiveness, concentration, nonaggressiveness, and absence of restlessness or distractibility. These factors contribute to early success in school, which then plays a significant role in determining children's long-term academic trajectories (e.g., placement in higher ability groups, more attention from teachers, greater motivation to do well). In addition, these early successes may also affect the types of activities in which children choose to engage; for example, good readers may choose to read more on their own. Each of these outcomes can then result in further success over time. In this way, the model posits a cascading effect in which early exposure to educational television leads to early academic success, which in turn, contributes to a long-term trajectory of success that can endure for years.

Important Scientific Research and Open Questions

Academic effects. Decades of research have demonstrated clearly that both preschool and school-age children learn from educational television series. Perhaps the most prominent – and certainly the most extensively researched – example of an educationally effective television series is *Sesame Street*. A number of major summative research studies have examined both immediate and long-term effects of *Sesame Street* on its viewers. Together, these studies demonstrate that extended viewing of *Sesame Street* produces significant immediate effects on a wide range of academic skills among preschool children (e.g., knowledge of the alphabet, vocabulary size, letter–word knowledge, math skills, sorting and classification, knowledge of shapes and body parts, relational terms, time spent reading and in educational activities, telling connected stories when pretending to read). In addition, several longitudinal studies have found long-term effects as well; for example, preschool viewers of *Sesame Street* were found to be more likely to read storybooks on their own and less likely to require remedial reading instruction 3 years later, when they subsequently entered first or second grade. Moreover, in the longest-term study to date, even high school students who had watched more educational television – and *Sesame Street* in particular – as preschoolers had significantly higher grades in English, Mathematics, and Science in junior high or high school. They also used books more often, showed higher academic self-esteem, and placed a higher value on academic performance. (See Fisch and Truglio 2001 for a review of these and other studies.)

Beyond this powerful evidence for the educational effectiveness of *Sesame Street*, numerous other studies show that *Sesame Street* is not alone in helping children learn. Summative studies on other educational series for preschool and school-age children have shown that educational television can enhance children's knowledge, skills, and attitudes in a wide variety of subject areas. These include effects of series such as *Between the Lions* and *The Electric Company* on children's language and literacy skills; *Square One TV* and *Cyberchase* on children's use of mathematics and problem solving; *3-2-1 Contact* and *Bill Nye the Science Guy* on children's understanding of science and technology; children's news programs on knowledge of current events; and preschool series such as *Blue's Clues* and *Barney and Friends* on more general school readiness. Many other examples exist as well. (See Fisch 2004 for a review.)

Prosocial effects. Parallel to the academic effects of educational television, numerous studies have found that viewing prosocial television programs produces significant positive changes in children's social behavior. Such effects have been documented as increases in several domains: "friendliness" and positive interactions in general, altruism and cooperation, self-control and delay of gratification, and reduction of stereotypes. Most of this research has been conducted with preschool children, so the bulk of the evidence to date relates to this age group. However, some research on stereotypes has been conducted with older children as well. (See Mares and Woodard 2001 for a review.)

Nevertheless, the impact of televised prosocial messages is likely to be mediated by lessons learned from family and peers, as well as children's own life experiences. In some cases, these experiences may work hand-in-hand with the prosocial lessons shown on-screen. In other cases, however, the messages from these various sources may conflict with each other. For example, research on race relations segments from *Sesame Street* found that preschool children recalled the fun things that young African-American and White characters did together on screen. However, they also recognized that their own parents would be less positive about their having playmates of other ethnicities (Truglio et al. 2001).

Emerging issues: *Learning among very young children.* For decades, virtually all of the studies regarding learning from educational television were conducted with children aged 3 years and above. In recent years, however, research has begun to explore learning among children under 3 years, spurred on by two primary developments: (a) a proliferation of commercial videos, and even entire digital channels, aimed at toddlers (e.g., *Baby Einstein*), and (b) a 1999 position statement by the American Academy of Pediatrics that recommended against any television viewing for children under 2 years. In the wake of these events, several studies have evaluated young children's ability either to learn from television, via either imitating actions seen on video or finding an object in a room after watching a video of the object being hidden. Together, these studies suggest that, below the age of two, some level of learning from video can occur, but learning is much stronger from live models than from models on video (see Anderson and Pempek 2005 for a review). However, considerably more research will be needed to determine whether this is due to inherent limitations in toddlers' ability to learn from television, or whether videos might be designed differently to better elicit learning among young children.

Nevertheless, whatever the case may be among toddlers, it is clear that older children can and do learn from educational television. Well-designed, age-appropriate television can be a powerful tool for informal education, to benefit a broad and diverse audience of children.

Cross-References

- ▶ Audiovisual Learning
- ▶ Games-Based Learning
- ▶ Human–Computer Interaction and Learning
- ▶ Informal Learning
- ▶ Interactive Videos
- ▶ Multimedia Learning
- ▶ Technology-Enhanced Learning Environments
- ▶ Video-Based Learning

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Choice Reaction Time and Learning

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Synonyms

2-Choice reaction time task; 4-Choice reaction time task; 5-Choice serial reaction time task

Definition

"**Reaction time**. *n.* The time elapsed between the onset of a stimulus and a response to it… Simple reaction time applies when there is only one possible stimulus requiring only one type of response; choice reaction time (CRT) when there are two or more possible stimuli requiring different responses" (Coleman 2001).

Choice reaction time (CRT) tasks are widely used to explore the physiological and psychological factors underlying "stimulus–response" (S–R) behavior, through the rapid identification and differential responding to multiple stimuli. The dependent variables are the reaction time and accuracy in making a correct choice to different, paired or multiple stimuli, which may be presented in either simultaneous or sequential mode. This contrasts with simple reaction time tasks where a single response is made to a single stimulus, with no decision or choice required of the subject. Originally designed for people, CRT tasks are now widely used in animal research as probes of focused and spatial attention, vigilance, neglect, and psychomotor learning, and are used primarily as probes of forebrain function. The present entry will focus on the use of these tests in rodents.

Theoretical Background

CRT tasks were first developed by Franciscus Cornelis Donders in the nineteenth century to assess psychomotor function (For review; Smith 1968). Three tasks were originally developed to dissect the different psychological processes involved in responding to a specific stimulus in a choice paradigm, based on a predefined rule. The first was a simple reaction time task – where the participant had to make a response to the appearance of one stimulus. The second was what we now term a go/no-go task (sometimes referred to as a recognition reaction time task) – where two different stimuli were presented independently and the participant had to respond in a set manner to one stimulus but refrain from responding to the second stimulus. The final was the development of a 2-choice reaction time task – where two separate stimuli were presented independently, with a different response required for each. By comparing the reaction times achieved on these three tasks, Donders developed a mathematical procedure termed the subtraction method, which worked out the time taken to categorize a stimulus and select an appropriate response. Following Donders work, research focused on theories of CRT performance using modifications of the two CRT task; hypothesizing on how stimuli were internally represented and categorized, and how correct responses were selected in order to perform such tasks (For review; Smith 1968). One example of this is Hick's law to determine the speed of CRT when an increasing number of stimuli are used. Hick (1952) stated that CRT increased logarithmically with the number of choices of stimuli. However, this law did not always hold true and was affected by the specific design of CRT task used.

Over the last century, not only have CRT tests evolved to probe very specific psychological phenomena that underlie human and animal behavior, but they have been utilized to examine psychomotor and attentional function following different manipulations of the normal physiological state. Such manipulations have included dehydration, stress, and hypoglycaemia, as well as examining the psychomotor effects of drugs and toxic substances. CRT tests are also widely used to probe neurological conditions including depression, schizophrenia, Huntington's disease, attention deficit hyperactivity disorder, Parkinson's disease and brain injury, and related treatment strategies, including pharmacological and cell-based interventions. In order to probe the defining deficits of such disorders, CRT tasks have been developed to assess very precise behavioral phenomena and the anatomical pathways and regions of the brain that subserve them.

In its most common form, CRT tasks present stimuli in a series, and the number of stimuli utilized can be anything from two choices upward, as can the number of possible responses. In the most basic paradigm, there are two stimuli and two responses. However, it is possible to have more stimuli than responses or visa versa. A further adaptation to the CRT paradigm are serial reaction time tasks. In a serial reaction time task trials are not presented as discrete trials, but instead administered as a continuous stream of stimuli, e.g., brief pulses of light presented in different locations, and the subjects are required to respond to the correct stimulus location by pushing a response button, touching a touch-screen, or (for rodents) nose poking into a hole, or pressing a lever as rapidly as possible. The number of locations used can be varied and randomly presented, thus introducing a spatial aspect to what is essentially a vigilance task, in which participants have to monitor the light array continuously for the appearance of the stimuli, and respond appropriately. This type of serial reaction time task can further be adapted to include sequences, either overt in a sequence learning task, or covert where predictable sequences are embedded within apparently randomized stimulus presentations. This covert use of sequences is designed to probe implicit learning in tasks such as the rodent serial implicit learning task (SILT). Another variation to the basic 2-CRT task, which is also used to examine attention, is the continuous performance task. During this task, subjects must respond to just one target stimulus within a stream of different stimuli, and all the other irrelevant stimuli must be ignored. This reaction time task is particularly sensitive to perseverative and disinhibitory changes.

Unlike in humans, where the rules for responding are explicitly explained to the participant before performing the test, animals have to be first trained on the particular S-R associations to be tested. Therefore, in this category of tests, not only is CRT examined, but also associative learning and habit formation. In rodents, CRT tasks run in the 9-hole box operant chamber or standard 2-lever "Skinner box" operant chambers depending on the design employed. In rats and mice, the most utilized of these tasks is the 5-choice serial reaction time task. This task is performed in the 9-hole operant chamber, as developed by Robbins and colleagues (For review: Robbins 2002). The animal must respond to light stimuli presented randomly across a horizontal 5-hole array, with each correct response resulting in the presentation of a reward. This test paradigm is regularly employed to assess the effects of drugs, or lesions on attentional performance of animals, and increasingly transgenic animals are being probed with this and other CRT tasks. The 5-choice serial reaction time task provides measures of reaction time, number of correct, premature, missed (errors of omission), and incorrect responses (errors of commission). When using this task, a number of probes can be introduced to assess attentional function, including randomizing the stimulus lengths, random intertrial intervals (time between trials) and bursts of white noise. Alternative versions of the task have been designed in which different numbers of stimuli are used. It is also possible to examine the effects of other manipulations, such as brain lesions to uncover the neural basis of attentional processing. In both animal and human studies, analysis of the error types provides a detailed description of the functional neuropathology of the individual, so whereas a reduction in accuracy may be demonstrated in a particular animal group, analysis of the error terms can provide a detailed description of why those errors are occurring, for example, the animal may be simply making the wrong choice, responding prematurely, perseverating in the previously correct hole, or may even become fixated with the food magazine. These errors indicate pathological processes related to specific neural substrates (For review: Robbins 2002).

A different type of CRT is the 2-CRT task for rodents, commonly known as the "Carli" task, which was also developed to probe lateralized responding by rats in the 9-hole operant box (Carli et al. 1985). This task has been used to assess motor function, sensory neglect, and the ability to initiate movements in unilateral lesion models of neurological disorders. The task is often used to assess unilaterally applied therapeutic interventions such as cell or neuroprotective gene therapies in lesion models of neurological disorders, including the excitotoxic model of Huntington's disease, the dopamine depletion model of Parkinson's disease, or unilateral middle cerebral artery occlusion as a model of ischemic stroke. In this task, only the central three holes of the 9-hole box are used. Rodents are trained to make a sustained nose poke into the center hole for a variable duration prior to a brief presentation of the stimulus light in either the left or right hole, to which the animal must respond. The dependent variables on this task are reaction time (time to withdraw from the center hole), which is a measure of the time required to detect the stimulus and initiate a motor response, and movement time (time to move from center hole to response hole) as a measure of motor function, as well as task accuracy. There are two versions of the task ("SAME" and "OPPOSITE"), which require the animal to respond either in the hole where the light was presented, or in the unlit hole, respectively. With the two versions of the task, it is possible to determine whether the deficits present in a unilateral animal model are due to sensory neglect or deficits in the ability to initiate movement. Different theoretical explanations of the functional processes underlying correct task performance – sensory, sensorimotor, or motor – make quite different predictions about the side on which a deficit will be observed in the two tasks in animals with unilateral lesions. The conventional "Carli" task has been further adapted to analyze discrimination between different choice response holes separately in ipsilateral (same side as the brain lesion) and contralateral (opposite side to brain lesion) space, which then allows analysis of whether lateralized deficits are related to egocentric (mapped by internal cues) or allocentric space (mapped by external cues) (Brasted et al. 1997). The "Carli" task, has demonstrated reliability as a test of psychomotor function, and offers the researcher the opportunity of dissecting motor from cognitive aspects of psychomotor function, which is a facility that few other tests offer.

Taken together, the CRT tasks are powerful and sensitive tools for uncovering psychological phenomena that are not detectable by other methodological approaches, and over the last 30 years of application to animal research have proved invaluable in uncovering the neuronal and chemical substrates of forebrain function.

Important Scientific Research and Open Questions

Within animal studies, the CRT tasks have been used to assess the neural origins of attention, initiation and control of movement, motor learning, and habit formation. This work contributes important insights into our understanding of the functioning of the normal brain as well as the processes underlying specific deficits within neurological disorders, and their treatment.

Cross-References

- ► Abilities and Learning: Psychomotor Abilities
- ► Associative Learning
- ► Attentional Learning and Habituation
- ► Implicit Learning
- ► Operant Behavior

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Choreographies of School Learning

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Synonyms

Choreographies of teaching; Didactics; Instructional design

Definition

The word choreography is derived from the Greek word choreia and the French – graphie. Choreia means "dance" and graphein, "to write, to describe." Choreography is "the art of symbolically representing dancing."

Choreographies of school learning are a metaphor to identify the complexity of the real interactions in the classroom. The choreography consists of a certain sequence of dance steps, which correspond to the learning steps. However, the dancer, here the learner, has a whole palette of free artistic elements, which she or he may insert and apply herself or himself.

The learner himself or herself must shape and understand the deep structure of the learning contents (music). This way, the metaphor emphasizes the dynamic, which appears in complex patterns. Behaviorism taught us that single variables have linear effects. Therefore, teaching research has tried to isolate and define characteristic features for good lessons (Hattie 2009; Seidel 2003). Today we know that quite many characteristics generate complicated patterns through their interaction and that these have more learning effects than other patterns (Fischler et al. 2002). Teaching patterns are based on scripts, which the teacher develops. A script is a kind of screenplay. Choreographies define the interaction and action repertoire for teachers and for students. They influence internal and control processes during apprenticeship and learning. Teaching quality is based on an orchestration of didactic approaches and basic didactic forms.

As an expert, the teacher knows her role, because she has a solid professional knowledge base. Thus he can classify his students on a continuum between novice and expert and adapts his lessons accordingly. Like a sports coach, she likewise has to know the epistemological obstacles to advance in the learning process. Besides his elaborated knowledge of the subject, he must know the developmental steps of learning, the meta-cognitive knowledge about the epistemology of knowledge and the teaching skills. What is the crucial point to be able to progress? The teacher, as a choreographer, is coaching the process from the novice to the expert.

Theoretical Background

Oser (Oser and Patry 1990; Oser et al. 1997; Oser and Baeriswyl 2001; Oser 2006) developed the theory of choreographies of teaching. His main hypothesis is that the "very sequence of (school) learning is based on a choreography that binds, on the one side, freedom of method, choice of social form and situated improvisation with, on the other side, the relatively rigor of the steps that are absolutely necessary in inner learning activity (Entwistle 2000; Charness et al. 2005; Hattie 2009). Such an hypothesis requires a double operationalization: Firstly, in view of the relationship between the basis-models and the visible structure, and secondly, in view of the rule-bound character already referred to on one hand and freedom to stimulate on the other" (Oser and Baeriswyl 2001, p. 1043).

The concept of basis models (BM) is, first of all, based on the differentiation between surface structure and deep structure of teaching and, secondly, based on the assumptions that the learning process precedes goals and is domain specific. If the learning goal is to build up certain values or attitudes, for example, in law or economics, the learning process must be choreographed differently, than if the goal is to build up conceptual knowledge. The surface structure includes all teaching methods (lectures, project learning, case studies, problem-based learning, anchored instruction, etc.), all social forms of learning (e.g., individual work, partner work, group work), all media, and media-based teaching forms. The surface or visible structure of lessons is directly observable. The surface structure of a lesson is not a major indicator of learning and teaching quality.

The deep structure refers to the learning process as a psychological process. It constitutes a construct and is therefore not directly observable. Oser has assumed that for every important learning area, sequences of the process can be described. The order of sequences can be normatively fixed. The right organization of this deep structure shall be the determining sign for quality of learning. A BM describes the learning sequences in regard to certain learning goals in a certain domain. It consists of those concatenations of operations or groups of operation, which are somehow necessary for every learner and cannot be replaced by anything else (Oser 1993). Such learning scripts as concatenations of operations can be viewed in two ways: They can be described as phenomena; for instance, when children construct a concept they proceed in such and such a way. Or, one can ask how teachers and children subjectively imagine such scripts. Both approaches complement one another (Oser and Baeriswyl 2001).

Twelve BM were developed altogether (Oser and Patry 1990):

1a. Learning through personal experience
1b. Discovery learning
2. Development as an aim of education
3. Problem solving
4a. Meaning building
4b. Concept building
5. Contemplative learning
6. Learning of strategies
7. Routines and skills
8. Motility
9. Social learning
10. Construction of values and value identity
11. Hypertext learning
12. Learning to negotiate

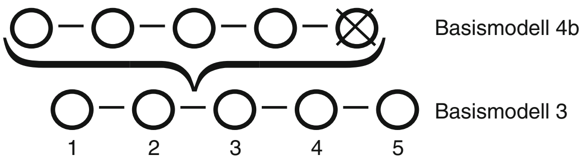
Each one of these models contains a defined deep structure of certain elements, which are chained together.

For example, model 1a consists of the following elements:

1. Anticipating and planning possible actions
2. Performance of the action
3. Constructing the meaning for the activity
4. Generalizing the experience
5. Reflecting similar experiences

A situated learning unit contains several basis models, which are intercalated.

Figure 1 shows an example of such an intercalation.



Choreographies of School Learning. Fig. 1 Insertion of basis model 4b, "concept building" into basis model 2, "problem solving" (Oser et al. 1997)

Important Scientific Research and Open Questions

The research about BM concentrates on the effects of BM-oriented teaching in contrast to regular instruction (Bauch-Schremmer 1993; Haenni 1996). It relies, on one hand, on the evidence of the configuration of single basic elements of a BM (Oser and Patry 1990; Oser et al. 1997) and, on the other hand, on the flexible and visible structure of the different elements of the BM.

In several investigations Oser et al. (1997) wanted to find out whether experienced teachers recognize the theoretically defined steps of the sequences of single basis models better than novices, or student teachers. They had to arrange the given step sequences properly.

The findings are that novices are further away from the theoretical structure than experts, and experienced teachers ordered the basis model 4 (concept finding) like the theoretical order.

The BM (1) learning through personal experience, (2) development as an aim of education, (3) problem solving, and (4) learning strategies were similarly well ordered by novices and teachers, but the theoretical orders were not recognized.

In another investigation (Oser et al. 1997), lessons were observed and analyzed in regard to how often and which BM was represented. The analysis of 40 lessons in different schools and levels show that the BM, "*concept building*" is represented by far the most often. The BM 1 "*learning through personal experience*" can only be observed in 12% of teaching time. In third place is "*learning of strategies.*" These findings show that the results of choreographies of teaching are quite one-sided. However, these results also correspond with the newer investigations on method variety in High Schools: Approximately 80% of teaching methods consists of conversation with the teacher or the "question–answer" method.

Bauch-Schremmer (1993) examined the learning success with a systematic use of the learning steps and with free arrangement of the learning steps. In English lessons the learning result was equal in both conditions. In the Technology lessons at High-School level, the strict use of a given learning step sequence was more successful.

Wagner (1999) examined the learning effect of the BM 4 (concept building). In one subject the BM lessons were more successful than the usual lessons. In another subject the results could not be replicated. Wagner (1999) has examined the lessons with BM for High-School level systematically and concludes:

Compared to customary lessons

- BM lessons lead to equally well teaching.
- BM lessons lead to a clearer structuring of the lessons.
- There are indications of a possible positive influence of BM lessons for the benefit of metacognitive abilities.
- The sequence of the learning steps cannot be guided exactly the way the BM theory describes it.
- Teachers can be overstrained with the differentiation of many BM and the use of specific goals.

With the choreographies of school learning Oser has emphasized the importance of comprehensive and deep processing and has pointed out the relative impact of methods and social forms. The newest meta-analysis on efficiency of instruction in school (Seidel and Shavelson 2007) confirms these findings. The elaboration of essential BM makes it possible to demonstrate the goal-oriented and situation-oriented moments in every instruction, as represented in the situated learning (Resnick 1991; Lave and Wenger 1991) and problem-based learning. These and further developments in didactics emphasize the impact which self-monitoring and one's self-responsibility has on deep processing and the process of learning.

The theory of the BM helps teachers to direct their focus on the learning process, since the use of new methods and media does not guarantee a better learning result. The central question remains: What must the learners do, in order to reach a deep and lasting understanding? The theory of BM describes learning as an action, where every action has a way and a goal. Learning requires specific planning which is not only the responsibility of the teacher, but the learner has to recognize it as a principle. The goal is that every student understands his or her learning as a planned act for which he takes the necessary responsibility. The strict sequencing and chaining of learning steps, as theorized, is probably not really necessary. The elements are important, and should be present (see also Bereiter and Scardamalia 2006). But the human mind has sufficient flexibility and does not require a strictly followed sequence of learning steps in order to learn successfully.

Cross-References

- ► Didactics (Didactic Models) and Learning
- ► Learning Strategies
- ► Teaching Methods

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Choreographies of Teaching

► Choreographies of School Learning

CHREST

A cognitive architecture, developed by Fernand Gobet and Peter Lane, emphasizing a close interaction between perception, learning, and memory. It proposes that human cognition is constrained by a number of limitations, such as span of attention and capacity of short-memory. Learning, which to some extent mitigates the limits imposed by bounded rationality, is done through the acquisition of chunks and templates. CHREST stands for Chunk Hierarchy and REtrieval STructures.

Chunks

A meaningful unit of information built from smaller pieces of information. Chunks consist of several items of information that have been learned and stored as a unit in long-term memory such as BMW, KGB, and USA. George Miller proposed that short-term memory can hold 7 +/− 2 chunks.

Cross-References

▶ Video-Based Learning

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Chunking

▶ Deductive Learning
▶ Restructuring in Learning

Chunking Mechanisms and Learning

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Definition

A ▶ chunk is a meaningful unit of information built from smaller pieces of information, and ▶ chunking is the process of creating a new chunk. Thus, a chunk can be seen as a collection of elements that have strong associations with one another, but weak associations with elements belonging to other chunks. Chunks, which can be of different sizes, are used by memory systems and more generally by the cognitive system. Within this broad definition, two further meanings can be differentiated. First, chunking can be seen as a deliberate, conscious process. Here, we talk about *goal-oriented chunking*. Second, chunking can be seen as a more automatic and continuous process that occurs during perception. Here, we talk about *perceptual chunking*.

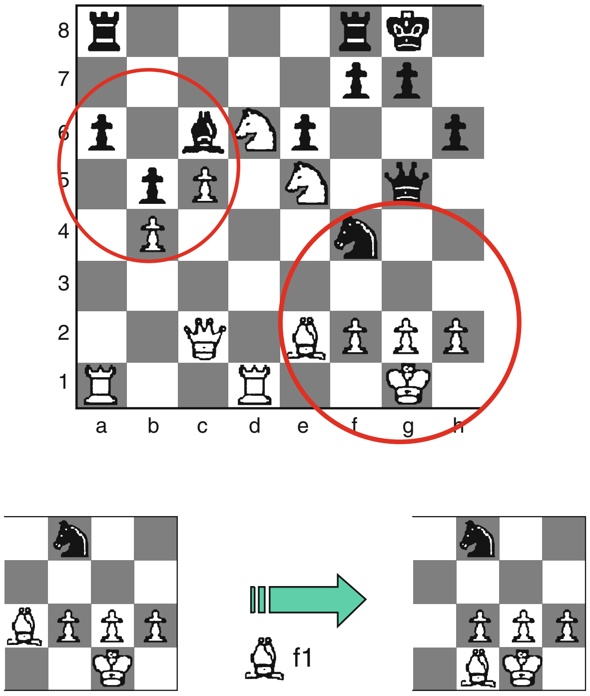
Theoretical Background

Chunking as a mechanism was initially proposed by De Groot (1946/1978) in his study of chess experts' perception, memory, and problem solving, to explain their ability to recall briefly presented positions with a high level of precision. It was also a central ingredient of Miller's (1956) classical article about the limits on human information-processing capacity. Miller proposed that chunks are the correct measure for the information in the human cognitive system, and that 7 ± 2 chunks can be held in short-term memory. Chase and Simon (1973) proposed a general theory of processes underpinning chunking. It is interesting to note that the approaches of De Groot as well as Chase and Simon emphasize the implicit nature of chunks, which are seen as the product of automatic learning processing sometimes called *perceptual chunking*. Miller's view emphasizes a type of strategic, *goal-oriented chunking*, where chunking is essentially re-coding of the information in a more efficient way. For example, the 9-digit binary number 101000111 can be re-coded as the 3-digit decimal number 327, making it easier to process and memorize for humans. The presence of chunks explains how humans, in spite of strict cognitive limitations in memory capacity, attention, and learning rate, can cope efficiently with the demands of the environment. Chunking has been established as one of the key mechanisms of human cognition and plays an important role in showing how internal cognitive processes are linked to the external environment.

There is considerable empirical evidence supporting the notion of a chunk, for example, in our ability to perceive words, sentences, or even paragraphs as single units, bypassing their representation as collections of letters or phonemes; this explains, for example, how skilled readers may be insensitive to word repetition or deletion. Particularly strong evidence is found in those studies that use information about the timing of responses to infer the presence of chunks. The use of response times assumes that the output of elements within a chunk will be faster than the output of elements across different chunks. This is because the elements within a chunk belong to the same structure, as well as sharing a number of relations. There is good empirical evidence confirming that subjects' pauses are shorter within chunks than between chunks. For example, timing information shows that when the alphabet is recited back, letters are grouped in clusters, and clusters grouped in superclusters. When trained to learn alphabets using scrambled letter orders, subjects also recall letters in a burst of activity followed by a pause and, therefore, show evidence for clusters.

The strongest empirical evidence for chunks is based on their inference from several converging methods. For example, studies on chess have shown that chunks identified by latencies in recall or placement of chess pieces correlate highly with chunks identified by the number of relations shared between successively placed pieces. By analyzing the patterns picked out by chess players within a position for various natural relations (including proximity, color, and relations of attack or defense), it is evident that within-chunk relations are much stronger than between-chunk relations. This pattern was found whether the subjects were asked to place pieces on the board from memory (using timings to separate the groups), or to copy a board (using the presence of glances between the two boards to separate the groups). Further empirical evidence for chunking has been uncovered in a number of other areas including artificial grammar learning, problem solving, and animal research.

The ► chunking theory, developed by Chase and Simon (1973) was an important attempt to formalize the mechanisms linked to chunking. It postulated that attention is serial and short-term memory is limited to about seven items (Miller's magical number). When individuals acquire information about a domain with practice and study, they acquire an increasingly larger number of chunks, which themselves tend to become larger, up to a limit of four or five items. While learning is assumed to be slow (10 s per chunk), recognition of the information stored in a chunk occurs in a matter of hundreds of milliseconds. Another important assumption is that chunks are linked to possible information. For example, in chess, the domain in which the theory was first applied, a chunk could provide information about potentially useful moves (see Fig. 1). Chunks help in a recall task, because groups of pieces rather than individual pieces can be stored in short-term memory. They also help in a problem-solving task, because some of the chunks, being linked to potentially useful information, provide clues about what kind of action should be taken.



Chunking Mechanisms and Learning. Fig. 1 *Top panel*: examples of chunks in a chess position. *Bottom panel*: one of the chunks elicits a possible move (retreating the white bishop)

There is also evidence that people, in particular experts in a domain, use higher-level representations than chunks. For example, data from chess research indicate that sometimes the entire position, up to 32 pieces, is handled as a single unit by grandmasters. In addition, evidence from expertise research indicates that information can sometimes be encoded in long-term memory faster than the 10 s proposed by chunking theory. Together, these results led to a revision of the chunking theory with the ► template theory (Gobet and Simon 1996). The template theory proposes that frequently used chunks become "templates," a type of ► schema. A template consists of a *core*, which contains constant information, and *slots*, where variable information can be stored. The presence of templates considerably expands experts' memory capability.

A methodological difficulty with research on chunking has been to precisely identify the boundaries between chunks. For example, the most direct explanation for observing a set of actions as a chunk is for the actions to be represented internally as a single unit, i.e., a chunk, and so retrieved and output together. However, it is also possible for a subject to plan output actions ahead, and so either break long sequences into subparts (e.g., to take a breath when reciting the alphabet) or else compose short sequences into what appear as longer ones (e.g., where a second chunk begins naturally from where the first one finished). Distinguishing between these types is only possible with the aid of a computational model, where the precise items of information known by the subject at a given point in time can be ascertained (Gobet et al. 2001). The advantage of using computer models is discussed in more detail in the entry on ► Learning in the CHREST Cognitive Architecture, a model based on the template theory.

Chunk-based theories, such as the chunking and template theories, not only provide a powerful explanation of learning and expert behavior, but also offer useful information as to how learning occurs in the classroom and how it could be improved (Gobet 2005). We briefly discuss some of the implications for education (further principles are listed in Table 1).

Chunking Mechanisms and Learning. Table 1
Educational principles derived from chunk-based theories (After Gobet 2005)

• Teach from the simple to the complex
• Teach from the known to the unknown
• The elements to be learned should be clearly identified
• Use an "improving spiral," where you come back to the same concepts and ideas and add increasingly more complex new information
• Focus on a limited number of types of standard problem situations, and teach the various methods in these situations thoroughly
• Repetition is necessary. Go over the same material several times, using varying points of view and a wide range of examples
• At the beginning, do not encourage students to carry out their own analysis of well-known problem situations, as they do not possess the key concepts yet
• Encourage students to find a balance between rote learning and understanding

A first implication of chunk-based theories is that acquiring a new chunk has a time cost, and therefore time at the task is essential, be it in mathematics or dancing. As documented by research into ► deliberate practice, practice must be tailored to the goal of improving performance. Chunk-based theories give attention a central role – see for example the CHREST model – and such theories are therefore suitable models of deliberate practice. In particular, conceptual knowledge is built on perceptual skills, which in turn must be anchored on concrete examples. Thus, curricula should provide means to acquire perceptual chunks in a given domain.

There are different useful ways to direct attention and to encourage the acquisition of perceptual chunks: to segment the curriculum into natural components, of the right size and difficulty; to present these components with an optimal ordering and suitable feedback; and to highlight the important features of a problem.

If perceptual chunking is an important way of storing knowledge, then a clear consequence is that transfer will be difficult. Unfortunately for learners, this prediction is correct, both for school knowledge and more specific skills such as sports and arts. More than 100 years of research have established that transfer is possible from one domain to another only when the components of the skills required in each domain overlap. Thus, it might be helpful to augment the teaching of specific knowledge with the teaching of metaheuristics – including strategies about how to learn, how to direct one's attention, and how to monitor and regulate one's limited cognitive resources.

As noted above, an important idea in Chase and Simon's (1973) theory is that perceptual chunks can be used as conditions to actions, thus leading to the acquisition of productions. Then, an important aspect of education is to balance the acquisition of the condition and action parts of productions. Another important aspect of education is to favor the acquisition of templates (schemata). Templates are created when the context offers both constant and variable information. As a consequence, and as is well established in the educational literature, it is essential to have variability during learning if templates are to be created.

Finally, chunk-based theories are fairly open to the possibility of large individual differences in people's cognitive abilities. In particular, while they postulate fixed parameters for short-term memory capacity and learning rates, it is plausible that these parameters vary between individuals. In addition, differences in knowledge will lead to individual differences in performance. A clear prediction of chunk-based theories is that individual differences play a large role in the early stages of learning, as is typical of classroom instruction, but tend to be less important after large amounts of knowledge have been acquired through practice and study.

Important Scientific Research and Open Questions

Chunk-based theories have spurred vigorous research in several aspects of learning and expertise. A first aspect is the acquisition of language, where recent research has shown that chunking plays an important role in the development of vocabulary and syntactic structures. A second aspect is related to the neurobiological basis of chunking. Recent results indicate that perceptual chunks are stored in the temporal lobe, and in particular the parahippocampal gyrus and fusiform gyrus.

Other issues being currently researched include the effect of order in learning, and in particular how curricula can be designed so that they optimize the transmission of knowledge. A possible avenue for future research is the design of computer tutors that use chunking principles for teaching various materials, optimizing instruction for the abilities and level of each student by providing personalized curricula, providing judicious feedback, and teaching strategies.

Cross-References

- ► Bounded Rationality and Learning
- ► Deliberate Practice
- ► Development of Expertise
- ► Learning in the CHREST Cognitive Architecture
- ► Schema

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Chunking Theory

Theory developed by Chase and Simon in 1973, explaining how experts circumvent the limitations of cognitive processes through the acquisition of domain-specific knowledge, in particular, small meaningful units of interconnected elements (chunks).

Circumscribed Interests

Circumscribed interests are a child's narrow preoccupations or ritualistic activity that is unusually intense in terms of their focus. Circumscribed interests often are characterized by difficulty removing the individual from engagement with the interest, high intensity of focus, and long duration of fascination and engagement with the interest. Circumscribed interests have been embedded in activities as a basis for promoting a child's participation and use of other behaviors (e.g., social interaction).

Cross-References

► Interest-Based Child Participation in Everyday Learning Activities

Civilization, Archaic

► Culture in Second Language Learning

Classical Conditioning

The procedure where an initially neutral stimulus, such as a tone, is repeatedly paired with a biologically significant stimulus, such as food. As a consequence, the tone elicits a response that anticipates the food.

Cross-References

- ▶ Associative Learning of Pictures and Words
- ▶ Attention and Pavlovian Conditioning
- ▶ Human Contingency Learning
- ▶ Pavlovian Conditioning

Classification

- ▶ Categorical Learning
- ▶ Concept Learning
- ▶ Supervised Learning

Classification of Educational Resources

- ▶ Classification of Learning Objects

Classification of Learning Objects

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Synonyms

Classification of educational resources; Taxonomy of educational resources; Taxonomy of learning objects

Definition

Classification is a process of management of knowledge to arrange the entities of a domain into a repository. The repositories follow rules and rational procedures for the presentation of the entities.

The term Learning Objects (LOs), by Wayne Odgins, dates back to 1994 and since then several definitions have been proposed which are different in semantics and aims. A term is not universally accepted for the description of an entity. Common terms are "instructional objects," "content objects," "knowledge objects," etc. In literature, an important definition is the one given by the IEEE that defines a learning object as "any entity, digital or non-digital, that may be used for learning, education or training" (Learning Technology Standards Committee – Institute of Electrical and Electronics Engineers 2002).

This definition, much too general according to some authors, has found in Wiley (Wiley 2000) one of the early references to the reusability as ontological criteria: "A Learning Object is any digital resource that can be reused to support the learning." Probably the most complete definition is the one recently given by Chiappe (Chiappe et al. 2007): "A digital self-contained and reusable entity, with a clear educational purpose, with at least three internal and editable components: content, learning activities and elements of context. The learning objects must have an external structure of information to facilitate their identification, storage and retrieval: the metadata."

Theoretical Background

The Learning Objects can have a different internal structure and fulfill various didactic aims but they commonly share the following characteristics:

- Didactic aim. The LOs are didactic objects and not only portions of content (Fini and Vanni 2004).
- Small size. The LOs must reflect a clearly defined content suitable to a flexible didactic planning (Mills 2002; Quin e Hobbs 2000).
- Reusable. The LOs must have assembly conditions to allow their reuse with no further repairing interventions need (Fini and Vanni 2004).
- Self-consistency. Any LO should need to rely on the content of other LOs to express a concept or to provide formative resources.

Some authors add "traceableness" and "portability" to the main characteristics of the LO.

The debate about the characteristics of the LO has implied many attempts of classification of the existing types of LOs. The classification is mainly based upon:

1. Formalized criteria
2. Human-usable systems

The former implies the use of taxonomies, the latter the adoption of classifying schemes depending upon the design and the designer.

Three taxonomies are particularly interesting within the classification based upon formalized criteria.

The first is Wiley's taxonomy (Wiley 2000), called "*Preliminary Taxonomy of Learning Object Types*." It focuses above all on the structural aspect of the LO. It counts five kinds of LOs having eight characteristics:

- Fundamental (i.e., a video of a hand typing on a keyboard)
- Combined–closed (i.e., a video of a hand typing on a keyboard with a background sound)
- Combined–open (i.e., a web page containing an image and a file containing an animation with an interactive text)
- Generative-presentation (i.e., a java applet able to generate an html page lay-out, or to show an editor with a correspondent code or to ask questions to the learner)
- Generative-instructional (i.e., an interface that teaches how to play an instrument)

Whereas the characteristics are:

- Number of elements combined: The number of the single elements (as video clips, images, etc.) which constitute the LO.
- Type of objects contained: The kinds of LOs that can set up a new LO.
- Reusable component objects: It indicates if it is possible to have access to the different components of LOs in order to reuse them in other learning contexts.
- Common function: The basic use of an LO.
- Extra-object dependence: It indicates if the LO needs other information about other LOs (i.e., the place on the web).
- Type of logic contained in object: It describes the function of the algorithms and the proceedings contained in the LO.
- Potential for inter-contextual reuse: It indicates the number of learning contexts in which the LO can be used, i.e., its potential to be reused.
- Potential for intra-contextual reuse: It highlights the times an LO can be reused within the same area or domain (Table 1).

The "*Educational Taxonomy for Learning Objects*" by Redeker (Redeker 2003) is the second taxonomy on which the OSEL taxonomy is based. It focuses above all on the didactics aspects related to the LO.The LOs are grouped into:

- Receptive: The learner is simply the beneficiary of the contents. Usually the learner's activity exploits LOs of little size.
- Internally interactive: There is interaction between user and computer. The LCMS or the models created by the teacher guide the learner.
- Cooperative: Containing brainstorming or problem-solving sessions which require communicative activities among the students.

The two taxonomies considered so far are respectively based on the relationships among the types and the characteristics (the former), and the interaction with the user (the latter) (Table 2).

The *Osel taxonomy* (IJKLO 2006) implies the joining of the two taxonomies, whose result is the creation of 15 different classes. Among these many cannot be considered valid by the research group.

The types of LOs considered admissible in the OSEL Taxonomy are nine:

- *B-simple*: It is the derivation of the classifying combination of fundamental (Wiley) and receptive (Redeker). It represents a noninteractive LO, made up of a single content constituted by a single element, or a simple media. Group activities are not allowed. For instance: a JPEG image or a text.
- *B-passive*: The classifying combination of combined–closed (Wiley) and receptive (Redeker). It represents a noninteractive LO having a single content made up of at least two internal elements combined between them. Group activities are not allowed. For instance: a JPEG image with textual description.
- *B-active*: The classifying combination of combined–open (Wiley) and receptive (Redeker). A noninteractive LO constituted by a single content made up of many internal and external elements combined among them. Group activities are not allowed. For instance: a textual description connected to many JPEG images, among which at least one is on an http out of the platform.
- *T-simple*: The classifying combination of basic (Wiley) and internal interactive (Redeker). An interactive LO constituted by at least two contents

Classification of Learning Objects. Table 1 Relationships among types and characteristics in Wiley's classification

Learning object characteristic	Fundamental learning object	Combined–closed learning object	Combined–open learning object	Generative-presentation learning object	Generative-instructional learning object
Number of elements combined	One	Few	Many	Few – many	Few – many
Type of objects contained	Single	Single, combined–closed	All	Single, combined–closed	Single, combined–closed, generative-presentation
Reusable component objects	(Not applicable)	No	Yes	Yes/no	Yes/No
Common function	Exhibit, display	Pre-designed instruction or practice	Pre-designed instruction and/or practice	Exhibit, display	Computer generated instruction and/or practice
Extra-object dependence	No	No	Yes	Yes/No	No
Type of logic contained in object	(Not applicable)	None, or answer sheet-based item scoring	None, or domain-specific instructional and assessment strategies	Domain-specific presentation strategies	Domain-independent presentation, instructional and assessment strategies
Potential for inter-contextual reuse	High	Medium	Low	High	High
Potential for intra-contextual reuse	Low	Low	Medium	High	High

Classification of Learning Objects. Table 2 Join of Wiley's and Redeker's taxonomies

		Preliminary taxonomy of the types of LOs (Wiley)		
		Fundamental	Combined–closed	Combined–open
Educational taxonomy (Redeker)	Receptive	Receptive–basic	Receptive–closed	Receptive–open
		B-simple	B-passive	B-Active
	Internally interactive	Interactive–basic	Interactive–closed	Interactive–open
		T-simple	T-passive	T-active
	Cooperative	Cooperative–basic	Cooperative–closed	Cooperative–open
		W-simple	W-passive	W-active

made up of a single element. Group activities are not allowed.

- *T-passive*: The classifying combination of combined–closed (Wiley) and internal interactive (Redeker). An interactive LO made up of at least two internal contents made up of at least two elements combined between them. Group activities are not allowed.
- *T-active*: The classifying combination of combined–open (Wiley) and internal interactive (Redeker). An interactive LO constituted by many internal and external contents having many elements combined among them. Group activities are not allowed.
- *W-simple*: The classifying combination of basic (Wiley) and cooperative (Redeker). An interactive

LO having at least two internal contents made up of a single element. Group activities are allowed.

- *W-passive*: The classifying combination of combined–closed (Wiley) and cooperative (Redeker). An interactive LO constituted by at least two internal elements combined between them. Group activities are allowed.
- *W-active*: The classifying combination of combined–open (Wiley) and cooperative (Redeker). An interactive LO constituted by many internal and external elements combined among them. Group activities are allowed.

The classifications based upon human-usable systems run on schemes depending upon the design and the approach, which can be top-down or bottom-up, or on the content typology mostly classified. Repository of digital contents, as Oercommons, Lemill, iCommons, have very different structures.

Oercommons classifies according to subjects (top level), educational levels, and resource types criteria; Lemill currently emphasizes the tags, classifying according to educational level (in detail), subject and language; iCommons classifies resources according to country, subject (very simple) and type.

Important Scientific Research and Open Question

The classification of LOs out of the context of use is important for the implementation of adaptable learning paths oriented to the creation or the compensation of competences in the academic or business environment.

Some models oriented toward the mitigation of the volatility of the plans, as the VALUABLE model (Boffoli et al. 2008), adopt tables of decision for the selection of LO sets for the acquisition of competences. It is obvious how the rigorous definition of the taxonomy adopted affects the efficacy of the model.

As concerns the classification based upon human-usable systems the research is focusing on the criteria that improve the efficiency of both the know-item seeking and the exhaustive seeking. The colon classification and the faceted classification which is derived from it are the most interesting schemes.

Cross-References

► Cognitive Models of Learning
► Courseware Learning

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Classification of Levels of Intellectual Behavior in Learning

► Bloom's Taxonomy of Learning Objectives

Classroom Discipline

► Classroom Management and Motivation

Classroom Management and Motivation

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Synonyms

Classroom discipline

Definition

Classroom management is an overarching term that refers to how a teacher structures the physical, instructional, and social arrangements in the classroom to create an environment that is conducive to learning. Jones and Jones (2010) offer a definition of classroom management that posits that effective teachers collaborate with students to minimize unproductive behaviors; intervene appropriately when unproductive behaviors occur; and the management system employed overall maximizes student engagement in ongoing, substantive, academic learning activities. Motivation is an essential construct to consider in terms of factors that influence students' engagement with curriculum and academic challenges (Anderman & Leake 2005). Understanding motivation as a key process in teaching is important for teachers if they are to effectively develop a motivational context that promotes engagement in the classroom environment and increases the possibilities for student learning (Anderman & Leake 2005; Brooks & Shell 2006).

Motivation has been defined as an internal process by which behavior is instantiated, guided, and maintained (Brooks & Shell 2006). Some have defined motivation through the lens of expectancy theories, which view motivation as a function of the degree to which a student believes they can possibly be successful with a given task and how much they value the rewards associated with the task. Jones and Jones (2010) add a third variable which they identify as "classroom climate." Classroom climate is defined as the quality of relationships in the task setting. This definition suggests student motivation is drawn from the interplay of a student's expectation that they can complete a given task successfully, the value they find in the task, and the extent to which the environment is supportive of their basic personal physical and psychological needs. Socio-cognitive theorists highlight the ways that motivation to participate changes as individual appraisals of the learning context respond to opportunities made available to students or requirements made of them by other individuals in the classroom setting (Na et al. 2010; Turner & Patrick 2008). Through this lens, motivation is defined as a set of dynamic constructs that is produced from the ongoing interaction between students' socially situated construals and the circumstances of the learning environment, influencing the subsequent sets of learning behaviors in which students engage (Na et al. 2010; Turner & Patrick 2008). Motivation in this sense is dynamic and situational, tied to how students change in response to their learning environments, and how learning environments change in response to students' actions. When motivation is considered in this fashion, classroom management strategies designed to enhance students' motivation to engage are not statically "effective" but depend a great deal on how the students, with their own backgrounds, engage in the classroom context. "Strategies are not inherently 'successful' and 'unsuccessful' but are defined by the interpersonal norms of the situation and by their cultural fit with the organization of teaching and learning" (Turner & Patrick 2008, p. 121).

Other theorists see motivation as a process by which human beings allocate working memory (Brooks & Shell 2006). From this perspective, motivation is defined in terms of how an individual selects the memory chunks they have available for use to activate in pursuit of a given learning goal or task. Motivation is redefined "in terms of the mental processes that a teacher must affect within a student before teacher-initiated learning has a chance to take place" (Brooks & Shell 2006, p. 26). This definition draws attention to the need for classroom environments to be designed to encourage learners to utilize sufficient working memory resources for learning to occur.

Theoretical Background

There is a high level of agreement among scholars in the field that motivation is a poorly explicated concept, made extremely difficult to understand in an integrated, ecologically valid manner due to the proliferation of numerous theories focusing on differing isolated aspects of motivation, all utilizing different constructs, models, and organizers (Anderman & Leake 2005; Keller 2008; Na et al. 2010). This proliferation of competing theories makes application of educational psychology insights on motivation to teaching and classroom management in the field confusing and problematic for practitioners. Traditional theoretical perspectives on motivation focus on how motives explain human behavior, with behaviorist, humanistic, and cognitive perspectives providing the foundational models (Na et al. 2010). Behavioral perspectives focus on empirical observations of outward behaviors instantiated in response to environmental stimuli, while humanisitic perspectives focus on motivation as a component of the internal dynamics of needs fulfillment. Cognitive approaches view motivation from the perspective of internal thought processes and their interaction with the external context. More recently, dynamic theories have posited that motivation is not a fixed phenomenon, but the result of continuously changing motivational states – for example, one's sense of self-efficacy – that have regulatory effects (Na et al. 2010). Socio-cognitive approaches view the social and the cognitive as inextricably intertwined with complex causal relationships that are not easily determined; from this vantage point complex behavior such as motivation is seen to be as much as a function of situations and contexts as it is a function of the individual (Turner & Patrick 2008). Some theorists view motivation as neurologically stored, thus occupying chunk spaces in working memory. Motivation is embedded in the allocations individuals make of their working memory chunks to a given task; in order for learning to occur, an individual must dedicate working memory resources to the task at hand (Brooks & Shell 2006). Several scholars have attempted to develop integrated models that incorporate aspects of multiple theoretical frameworks. For example, Keller (2008) offers an integrative, concatenated theory of motivation to help explain the relationships among motivation, volition, and performance as they relate to learning. Keller posits that an individual's motivational needs and corresponding strategy selection are based in attention, relevance, confidence, and satisfaction. Internal volitional self-regulatory processes with external supports help learners move from goal selection to action and persistence to task and complete the motivation cycle from initial interest to intitial engagement to sustained engagement (Keller 2008).

The outcome of this extensive theoretical construction and attendant research around motivation has been the development of a variety of frameworks for teaching practice that consider the motivational context of learning environments (Na et al. 2010). Recommendations for practice in the area of classroom environmental design and management to enhance motivation have been offered from a variety of perspectives. Keller (2008) suggests that there are a variety of classroom environmental influences, including teacher enthusiasm, quality of instruction, clarity of expectations, and availability of resources, that influence goal-directed effort which can increase the likelihood of enhanced achievement and performance among learners within the context of their innate individual abilities. Anderman and Leake (2005) offer an integrative framework that incorporates an array of socio-cognitive theories to assist practitioners in the application of motivational principles established in the psychology literature to teaching and classroom management. This framework is based on three fundamental needs of learners: the need for autonomy, the need for belonging, and the need for competence. In this framework, constructs of intrinsic and extrinsic motivation; locus of control; internal and external attribution; self-regulation; task values and expectancy are all housed under the category of autonomy, with the suggestion that internal sense of control and self-determination enhances motivation. From this perspective, classroom management practices that enhance motivation include those that release responsibility to the learners; encourage students to feel a sense of individual empowerment; facilitate connections to students' lives and personal interests; emphasize intrinsic rewards; allow choice; and help students develop behavioral and cognitive self-regulation (Anderman & Leake 2005; Jones & Jones 2010). Furthermore, motivation, particularly among novice learners who do not have huge bodies of prior knowledge on which to draw, requires conscious and explicit self-regulation strategies to initiate and sustain engagement in a learning task (Brooks & Shell 2006). These strategies promote motivation to engage in learning and thus improve the likelihood that learning occurs. However, because they are conscious and explicit, they consume some of the working memory that would otherwise be available for learning, and if overdone can impede learning (Brooks & Shell 2006). Theorists that focus on motivation from this perspective view it as imperative that the classroom environment structure ways to balance the contrasting needs of novice learners for explicit instruction in and development of self-regulatory strategies with the need to make sure such tools do not cause excessive distraction (Brooks & Shell 2006). Classroom management strategies that may be helpful in terms of assisting learners in their ability to regulate motivation include structuring opportunities for students to identify and provide their own consequences for behavior; teaching students goal-orientated self-talk strategies; subdividing and teaching students how to subdivide task into smaller chunks; and teaching students to adopt attributional control strategies that help them view engagement and potential success as within their own personal control (Brooks & Shell 2006).

The need for belonging serves as a second category under which to discuss constructs relating to motivation (Anderman & Leake 2005). People have a psychological need for belonging or attachment to other human beings. From this perspective, motivation is seen to be enhanced in classroom environments where the classroom management plan has taken into account specific approaches to building teacher–student and peer relationships that are mutually respectful and help learners feel connected to others in the environment (Anderman & Leake 2005; Jones & Jones 2010). These may include such approaches as holding regular class meetings; offering students ways to express their opinions and feelings to each other and privately with the teacher; explicitly teaching and practicing the social skills necessary for successful learning and social interactions in the classroom; and implementing systems of behavioral management that focus on engaging students in identifying prosocial behaviors for effective learning and reflecting on the outcomes of their own behavioral choices (Jones & Jones 2010). Attention to the recognition of unintended bias, differential expectations, and planning to ensure equal participation and inclusion also support the development of a relational motivational context that promotes engagement in learning tasks among students (Anderman & Leake 2005; Jones & Jones 2010).

Finally, competence is a category under which many of the theoretical constructs relating to motivation might be grouped, including those related to expectancy beliefs, goal setting, attributions, self-concept, and self-efficacy (Anderman & Leake 2005). All human beings have some underlying need to feel that they can be capable and successful with the tasks they undertake. Research has shown that when students feel competent, they feel more certain that they can be successful with a wider range of learning tasks, which in turn enhances the likelihood that they will initiate and sustain engagement in learning (Anderman & Leake 2005). A success cycle is established whereby successful learning leads to enhanced self-efficacy, which can therefore lead to increased motivation to engage in learning tasks and therefore more opportunities for successful learning (Brooks & Shell 2006). Classroom management practices for enhancing these aspects of the motivational context in a classroom environment include helping students set attainable goals; teaching students to adaptively attribute their successes and challenges with given tasks; providing students with realistic and immediate feedback that enhances self-efficacy; and providing learning opportunities and materials matched to students' learning styles and strengths (Anderman & Leake 2005; Jones & Jones 2010).

Important Scientific Research and Open Questions

There is a wide body of research on the relationships among varying discrete concepts relating to motivation, such as interest, goal orientation, self-efficacy, outcome expectancy, attributional orientations, cognitive engagement, intrinsic and extrinsic motivation, locus of control, task value, and self-efficacy (Anderman & Leake 2005; Keller 2008; Na et al. 2010). However, there has been little systematic research done that has yielded a comprehensive understanding of how teachers can foster the development of motivation among particular students in specific classroom environments (Na et al. 2010; Turner & Patrick 2008). Turner and Patrick (2008) suggest that in order to develop a research agenda that yields findings that are useful to practitioners, the focus of research on motivation should be turned toward analysis of students' participation in groups, in the context of how various groups construe tasks differently. Additionally, while much research has focused on ways to increase learner success through self-regulation, comparatively little has been done with an explicit focus on the regulation of motivation (Brooks & Shell 2006). The classroom management structures teachers put in place may promote or discourage the development among students of various self-regulatory tools for managing motivation; this is an area in which additional empirical research is needed.

Cross-References

▶ Learning Motivation of Disadvantaged Students
▶ Motivation Enhancement
▶ Motivation, Volition and Performance
▶ Multifaceted Nature of Intrinsic Motivation
▶ School Motivation
▶ Self-Regulation and Motivation Strategies
▶ Understanding Intrinsic and Extrinsic Motivation

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Classroom Teaching and Learning

▶ Didactics, Didactic Models and Learning

Classroom-Based Knowledge Construction

▶ Rapid Collaborative Knowledge Improvement

Classwide Peer Tutoring

▶ Reciprocal Learning

"Clever Hans": Involuntary and Unconscious Cueing

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Synonyms

Impulsive cueing; Instinctive cueing

Definition

Cueing has different definitions in different contexts. Here, the definition is limited to the context of responding to externally provided stimuli. Cueing is another name for "foldback," which is a process used to return a signal to a performer instantly. Cueing is achieved via prompts, signals, hints or, more generally, *cues,* which include anything that is connected in some way to information to be processed and which prompts its retrieval. This entry refers to the story of "Clever Hans," which can serve as a splendid example of involuntary and unconscious cueing.

Theoretical Background

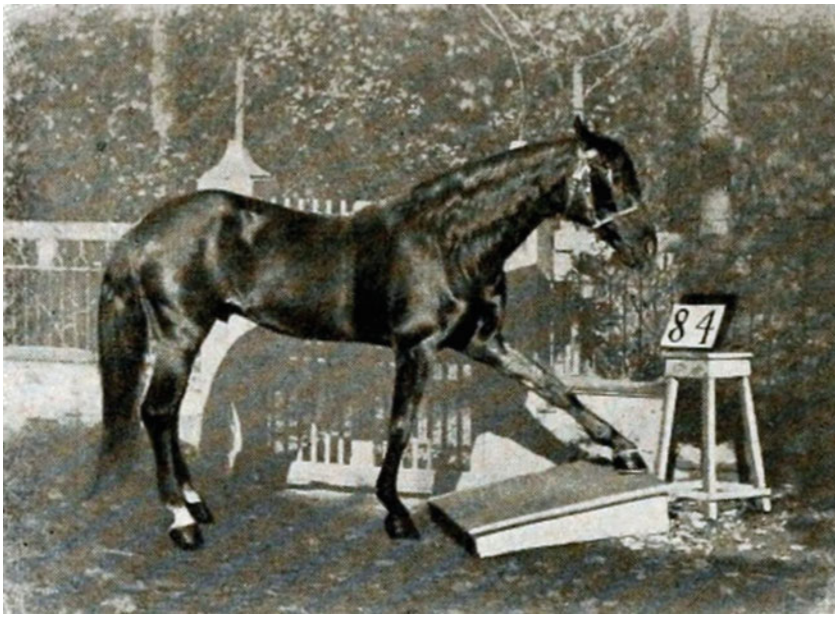
Involuntary and unconscious cueing can be illustrated by referring to the story of Clever Hans from the end of the nineteenth century. Clever Hans was an Arab stallion from Russia. His owner, Wilhelm von Osten, a retired schoolmaster, was convinced that animals possess an intelligence comparable to that of humans. After many unsuccessful attempts to teach animals, he found in Hans a partner for life. Von Osten taught the horse to respond to questions requiring mathematical calculations by tapping his hoof. If Hans was asked, for instance, what the sum of 3 plus 2 is, the horse would tap his hoof five times. It appeared that the horse was responding to human language and was capable of grasping mathematical concepts. In a short time, Hans was able to work out reasonably complex calculations, including some square roots. The horse could also tell time and name people, but in the literature the focus is usually on his mathematical skills.

In the 1890s, von Osten began to showing his intelligent horse to the public. Clever Hans and his owner enjoyed worldwide acclaim, but the scientific community remained skeptical. Clever Hans had been tested by many people. He mastered each test successfully and the observers could not see any trickery. As a consequence, it was claimed that Hans had the intellectual ability of a 14-year-old boy (Fig. 1).

Clever Hans became a real sensation and people flocked to see his demonstrations when Professor Carl Stumpf completed a first scientific testing in 1904 and certified Hans's ability as genuine (Freund 1904). Other scientists, however, remained skeptical. Therefore, Oskar Pfungst retested Hans in 1907, applying a more rigorous test setting (Pfungst 1911/1998). A group of 13 scientists was assembled, known as the "Hans Commission." Pfungst had the idea to separate Hans from his owner as well as from any other person. While one member of the team wrote down the numbers and left the room, everyone else moved behind the blackboard. Thus, only the horse could know what was inscribed on the blackboard. Now Clever Hans failed every test. Pfungst concluded that when the correct answer was not known to anyone present in the room, the horse did not know it either. More specifically, the test demonstrated effects of involuntary and unconsciousness cueing. It became apparent that Hans needed some visual contact with the questioner in order to answer correctly. The further away the questioner was, the less accurate Hans became, and when he was blinkered his ability to answer diminished even further. The second major finding was that Hans could only answer correctly if the questioner also knew the answer to the question. When the questioner did not know the answer to the question, Hans could not find the answer.

Based on these observations, the "Hans Commission" concluded that Hans was not using intelligence to work out the answers but was responding to visual cues provided by the questioner or other present persons. Although the people interacting with Hans were not conscious of providing him with cues, the horse was simply responding to muscle tensions, facial expressions, and other involuntary cues produced in interacting with Hans. No evidence of cheating was found.

Thus, people were cueing Hans unconsciously by tensing their muscles until he produced the correct answer. The horse really was clever because he could perceive and "interpret" very subtle muscle movements. Although Hans could not process human language as his owner maintained, he had an ability of some kind to respond to involuntary and unconscious cues in his environment. People can unconsciously communicate information through subtle movements of muscles, and some animals can perceive these unconscious and involuntary cues.



"Clever Hans": Involuntary and Unconscious Cueing. Fig. 1 Clever Hans in a test situation

Important Scientific Research and Open Questions

The experiments with Clever Hans revealed to psychologists that a person's or an animal's behavior in a situation can be influenced by subtle and unintentional cueing. This effect is now known as the "Clever Hans effect" and has implications in all interactive situations, such as test situations where unconscious cueing from testers can introduce a bias to testing and affect its reliability. In scientific tests and research, the "Clever Hans effect" can only be controlled by means of ► double-blind experiments, and tests in which neither the experimenter nor the subject is aware of the treatments or tests being given (see, for example, Bateman et al. 2004; Conners et al. 1976).

Involuntary and unconscious cueing has not only been observed in the case of Clever Hans. For example, James Randi (1995), known as a professional magician ("The Amazing Randi"), author, lecturer, amateur archaeologist, and astronomer, refers to the story of J.B. Rhine, who declared that the horse Lady Wonder was psychic because she could answer questions by knocking over alphabet blocks. In Rhine's opinion, there was no trickery involved. He concluded that the only tenable hypothesis for the horse's abilities was that the horse was telepathic. Rhine's first test of Lady Wonder was in 1927. However, 2 years later, the horse had lost its telepathic abilities. Rhine's reasoning is an example of the false dilemma fallacy.

Nevertheless, until today, unconscious cueing supports many people's strong belief in the psychic abilities of animals. Animals are thought to show evidence of possessing intellectual abilities, such as linguistic abilities (Sebeok and Umiker-Sebeok 1980), and humans are thought to be capable of subliminal information processing when they are sensitive to the involuntary and unconscious cueing of others.

Cross-References

► Animal Learning and Intelligence
► Attention and Implicit Learning
► Context Conditioning
► Cued Recall
► Cueing
► Implicit Attentional Learning
► Intelligent Communication in Social Animals

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Climate of Learning

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Synonyms

Atmosphere of learning; Learning environment; Teaching environment

Definition

The term climate often is associated with weather and is defined as the meterological conditions of a particular area or region. In the context of learning sciences, climate of learning refers to the social, emotional, and physical conditions under which one acquires knowledge. The climate that surrounds learning is predominantly thought of within a classroom context but is also present wherever learning takes place, as in tutoring, mentoring, coaching, and on the job training. Factors associated with the tone and atmosphere of a learning setting can significantly influence learning processes. Ideally, teachers create learning environments that meet the developmental needs of their students through positive student–teacher relationships, enthusiastic and quality instruction, and high expectations for learning-related behavior and academic achievement. The climate of learning is a specific component of school climate and school culture, which are a much broader set of factors that may influence student achievement.

Theoretical Background

In 1924, a group of researchers conducted a study on the relationship between light intensity and employee productivity at Hawthorne Works, a Western Electric plant near Chicago, Illinois. Researchers increased and decreased light intensity and changed other factors of the workday, but the results were inconclusive. After 9 years of research and interviews with employees, investigators discovered that when workers felt valued and understood, their productivity increased. This finding is known as the "Hawthorne Effect," and it illuminated the social and emotional influence of climate on human productivity and motivation (Sonnenfeld 1985).

Consistent with the findings in the Hawthorne Study, learning cannot be separated from the social, emotional, and physical factors that surround it. According to Dr. Urie Bronfenbrenner's bioecological perspective on human development, "Human beings create the environments that shape the course of human development (2004, p. 28)." Learning and development occurs within an interconnected set of systemic levels. The microsystem consists of people and places with whom the child has the most contact, such as family members at home, and teachers and staff at school. In the microsystem, learning experiences are bidirectional; both the learner and the teacher shape the climate of learning. The intermediate level consists of indirect influences on the child such as parental work environment (e.g., income level, parental work schedules), and community services. The outermost level, the macrosystem, consists of global contexts such as the state and federal economic systems, prevailing cultural norms, and societal laws. Each systemic level is interconnected, and all play a role in shaping development.

Acccording to social learning theory, people learn by interacting with others. Learners acquire skills, strategies, and beliefs by observing and modeling others in their environment. Albert Bandura, considered to be the father of observational learning, believes there are four processes necessary for observational learning: attention (children are attracted to high status, same-sex models), retention (committing a behavior to memory), production (imitating the behavior), and motivation (the child must be motivated to replicate the behavior). Bandura's well-known 1964 Bobo doll study demonstrated the effects of observational learning in young children.

Several learning theories exist, and have a direct effect on the climate of learning. B.F. Skinner, considered the father of behaviorism, demonstrated that behaviors that are rewarded increase in frequency, while those that are punished decrease in frequency. Teachers shape the learning climate in accordance with the theory or theories they find most compelling. Cognitive learning theory focuses on how humans perceive, store, and remember information. Constructivist learning, also known as discovery learning, encourages students to discover concepts and principles through personal exploration and activation of prior knowledge. Experiential learning, also referred to as service learning, emphasizes learning through direct experiences. The Montessori approach to learning places special emphasis on individual development levels, and encourages children to be self-directed, cooperative learners. Students pursue their own academic interests and complete work at their own pace.

Important Scientific Research and Open Questions

Since the National Commission on Excellence in Education published "A Nation at Risk" in 1983, the American Public has become more aware of school performance and student achievement. As a result of this report, more attention was placed on standardized test scores that emphasize mathematical and linguistic aptitude to measure student achievement. Recently, the No Child Left Behind Act of 2001 has increased the emphasis on standardized testing and student achievement to a greater degree. As a result, most of the time, energy, and resources in schools are channeled toward teaching to the test. Social and emotional facets of education are often usurped by the pursuit of greater academic achievement. However, research indicates that the climate of learning is an important variable that can have direct implications on student achievement. Solid classroom management techniques, clear and high expectations, and positive, respectful interactions between students and teachers are components of the learning climate. Though they are social and emotional in nature, they have a direct impact on student achievement. When classroom management techniques that minimize disruptions to learning are utilized, students spend more time engaged academically and perform better (Freiberg et al. 2009).

Parents send their children to school with the expectation that their students will become lifelong learners and happy, well-adjusted members of society (Cohen 2006). Cohen's research indicated that parents are more concerned about their children's social and emotional functioning as adults, as opposed to their academic functioning. However, in the American education curriculum, little emphasis is placed on teaching students social, emotional, and ethical skills. Yet, a strong social, emotional, and ethical curriculum is necessary to produce citizens who will actively participate in a democracy. Cohen argues that the lack of such a curriculum is not only an injustice to American schoolchildren, but also a violation of their human rights (2006). Even the Founding Fathers indicated that all citizens are entitled to "The pursuit of happiness." Children deserve a holistic education that addresses their academic, social, emotional, and physical needs.

Knowles also noted the discrepancy between how children are taught and what they need to learn. In order for children to become healthy adults, they must become self-directed learners (Knowles 1970). Traditional pedagogical methods often view students as sponges, soaking up knowledge with little input or experience to draw from and creating dependency on the teacher. The climate of learning is a crucial element in the maturation process and encouraging self-direction. Students must feel respected, accepted, supported, and physically comfortable in order to reach their fullest potential (Knowles 1970).

The movement to incorporate social and emotional education into school curriculums is growing. In 1994, Daniel Goleman, author of ► Emotional Intelligence, cofounded CASEL (Collaborative for Academic, Social, and Emotional Learning) along with Eileen Rockefeller Growald. CASEL is a nonprofit organization dedicated to advancing scholarly research and broadening the evidence base for social and emotional learning from preschool to high school (CASEL 2010). CASEL has developed curriculum materials for schools across the country. The following are the core beliefs of CASEL, obtained from the CASEL Web site:

- Adults have a responsibility to help children to become knowledgeable, responsible, healthy, caring, and contributing members of society.
- Rigorous science provides an essential foundation for effective educational policies and practices; a core aspect of rigorous science is to ground development and testing in real-life settings and conditions.
- Effective, integrated SEL programming is the most promising educational reform to promote the academic success, engaged citizenship, healthy actions, and well-being of children.
- Cross-disciplinary collaboration produces the richest insights, biggest impacts, and best outcomes in work on behalf of children.
- We strive for excellence in all our work. We have high expectations for ourselves, and we encourage and expect the best from others.
- CASEL leadership, staff, and collaborators must model social and emotional competence and ethical behavior.

Learning is a lifelong, holistic endeavor and is neither limited to a classroom, nor the first 18 years of life. Athletes learn from coaches and teammates on the athletic field. The resident learns from the practicing physician. The journeyman teaches and guides the apprentice. A Girl Scout learns financial literacy skills from her dedicated leader. A university student logs on to his computer, fulfilling requirements for an online course. Wherever learning takes place, a learning climate exists. The social, emotional, and physical impact of the learning climate profoundly shapes the learning experience.

Online learning environments are growing in popularity, and accommodate a wide range of lifestyles. Many universities, secondary schools, and home schooling associations are taking advantage of online learning communities. This new learning environment creates the need for a solid research base on the social and emotional effects of online learning climates. Do blogs and discussion boards provide the same opportunities for comprehension and retention of material as more traditional, face-to-face classroom discussions? Is human interaction necessary to form a learning climate? How will online learning climates continue to impact education?

Cross-References

- ► Affective Dimensions of Learning
- ► Conditions of Learning
- ► Learning Space
- ► School Climate and Learning
- ► Synthetic Learning Environment

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Clinical Placement

► Learning in Practice and by Experience

Closed-Loop Process

Process using information about its outcomes as input.

Clue

► Cue Summation and Learning

Clustering

► Social Influence and the Emergence of Cultural Norms

Coaching and Mentoring

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Synonyms

Apprenticeship; Guided problem solving; Tutoring

Definition

Coaching and mentoring are related concepts that both fall under the general category of *developmental interactions* (D'Abate et al. 2003) and involve the provision of guidance by an expert to a novice who is seeking to acquire specific skills or knowledge. The terms are used commonly in organizational settings, but are also applicable more broadly to academic and physical skill contexts. Guidance from a coach or mentor is delivered in goal-directed ways, such as to help the learner complete a task or gain understanding about a specific concept or perspective. Mentoring is generally understood as a relationship-oriented activity that occurs over longer periods of time and includes career- and psychosocial-related support for the learner. The roots of the term *mentor* lie in Greek mythology where it describes "a relationship between a younger adult and an older, more experienced adult [who] helps the younger individual learn to navigate the adult world and the world of work" (Kram 1985, p. 2). Coaching is typically thought of as a skill that good mentors possess. It is more focused and involves scaffolding a learner (or protégé) through the steps of a specific task. According to Allan Collins (2006), coaching "consists of observing students while they carry out a task and offering hints, challenges, scaffolding, feedback, modeling, reminders, and new tasks aimed at bringing their performance closer to expert performance. Coaching is related to specific events or problems that arise as the student attempts to accomplish the task." (p. 51)

Theoretical Background

Modern conceptions of coaching and mentoring have their roots in apprenticeship, the form of teaching and learning dominant throughout most of history (Collins 2006, p. 47). In an apprenticeship, a master teaches a novice his/her art and/or skill *in situ* with the focus on practical skill development for real-world tasks. For example, carpenters and bakers very commonly passed along their skills and knowledge via apprenticeships in their actual working environments. This is in contrast to modern schools, where the goal is usually to teach abstract forms of knowledge for the purposes of reuse across varied contexts. The three key components to an apprenticeship are *modeling*, *coaching*, and *practice*. Modeling is mostly passive for the apprentice: he repeatedly observes and studies the master executing the skill while possibly receiving didactic instruction and explanations along the way. Next, the apprentice attempts to execute the skill through practice. This must be supported by guidance from the master since the apprentice will most likely not be able to complete the task on his or her own in the early stages. As the apprentice continues practicing, the need for coaching diminishes, and the master *fades* the support until the point that the apprentice is able to execute the task independently. Deciding when to deliver and fade this support is at the heart of coaching and may include such pedagogical interventions as hints, feedback, questions, suggestions, corrections, new tasks, explanations, reflection, and more (Collins 2006; Merrill et al. 1992).

In an effort to modernize the notion of apprenticeship to account for skills such as reading and mathematics, Allan Collins and John Seely Brown have elaborated on the idea of *cognitive apprenticeship*. Here, the focus is on cognitive skills and is differentiated from traditional apprenticeship by (1) taking problems not from the workplace, but rather selected based on the skills necessary to solve them, and (2) placing emphasis not on context-specific skills, but rather on generalization and reuse in different settings (Collins 2006, pp. 48–49). Not surprisingly, coaching shares many functional similarities with *tutoring*, a term usually reserved for use in academic and other formal schooling contexts. Analysis of the best expert human tutors and intelligent tutoring systems reveal that they (1) allow students to do as much of the work as possible, (2) frequently intervene after an *impasse* (a time when the student becomes "stuck" and unsure about how to proceed), and (3) engage in *coached problem solving*, a step-by-step monitoring and support process based on the ideas of coaching during practice in an apprenticeship (Merrill et al. 1992). Key decisions that a tutor (or coach) must make involve the selection of appropriate problems, when to intervene, what hints and/or feedback to give, what questions to ask, and how quickly (or slowly) to fade the support over time.

In organizational psychology and business literature, there is limited agreement on the specific activities involved in coaching, mentoring, or more generally, developmental interactions. For example, a literature review on developmental interactions revealed that only 30% of characteristics linked to traditional mentoring were used consistently (D'Abate et al. 2003, p. 377). However, there is widespread agreement that in addition to coaching, conceptualizations of mentoring tends to include activities focused on career- and psychosocial-related issues (Allen et al. 2004, p. 128). While the goal of a coaching interaction is usually concrete and focused on skill development, mentoring is more about long-term outcomes and individual development. Mentoring strategies frequently reach well beyond the cognitive growth of the learner. For example, expert mentors routinely engage in relationship-building activities such as providing support for the effective management of family and work lives. Other techniques include the assignment of challenging tasks, exposure to new people or career paths, and protection of their protégé in the work environment (Kram 1985). Studies that seek to demonstrate the efficacy of mentoring programs tend to promote learning and career development and focus on *objective* and *subjective* outcomes. Objective outcomes include markers of career-related growth, like promotions and compensation. Subjective assessment usually involves psychometric measures of satisfaction, commitment, turnover, and other affective measures (Allen et al. 2004).

Important Scientific Research and Open Questions

For the acquisition of cognitive skills, professional one-to-one human tutoring is generally believed to be the best known method of teaching available in the world since it produces learning gains of roughly two standard deviations above the mean when compared to classroom learning (Bloom 1984). Researchers of intelligent tutoring systems are often driven to achieve this with computer tutors. To date, the best intelligent tutors are able to achieve a one standard deviation improvement over classroom learning. Mentoring studies have also generally supported the belief that mentoring has a positive effect on career development including positive impacts on objective measures, including compensation and promotion, as well as subjective measures commitment, satisfaction, and expectations for advancement (Allen et al. 2004).

Important empirical questions remain unanswered about both coaching and mentoring. Consistent patterns do emerge from the study of expert coaches and tutors, such as providing immediate feedback and intervening on impasses, but the question of why specific interventions promote learning, and how individual differences factor into success or failure, remain critical areas for investigation. Also, although fading of support in a coaching session is nearly universal in expert coaching, tutoring, and mentoring, the *rate* of this fading (how quickly the scaffolding is removed), and the dimensions along which it is best to fade (e.g., timing vs. content), remain as important open questions that deserve study. In the mentoring literature, there are similar open questions regarding the ideal timing for interventions in career development. Long-term studies are needed that compare mentored vs. non-mentored employees, and uncover why different interventions succeed or fail to promote objective and subjective measures of development in the workplace. Finally, significant open questions remain on the role of learner emotions during coaching and mentoring that require further research. For example, empirical studies to date have produced mixed results with respect to connections between motivational developmental interactions and career advancement (Allen et al. 2004, pp. 133–134).

Cross-References

- ▶ Cognitive Apprenticeship Learning
- ▶ Deliberate Practice
- ▶ Feedback in Instructional Contexts
- ▶ Feedback Strategies
- ▶ Guidance Fading Effect
- ▶ Guided Learning
- ▶ Human–Computer Interaction and Learning
- ▶ Intelligent Tutorials and Effects on Learning
- ▶ Scaffolding Learning

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Code-Cognition Approach

▶ Cognitive-Code Learning

Cognition

How information, either in the external environment, or internally generated, is processed. Cognition can refer to memory, attention, emotion, perception, and other similar processes that involve knowledge and understanding of the world.

Cross-References

- ▶ Early Maladaptive Schemas: The Moderating Effects of Optimism
- ▶ Infant Learning and Memory
- ▶ Problem Solving

Cognition About Cognition

▶ Metacognitive Processes in Change and Therapy

Cognition in Invertebrates

► Learning in Invertebrates

Cognitive Abilities and Skill

► Ability Determinants of Complex Skill Acquisition

Cognitive Ability

► Intelligence, Learning, and Neural Plasticity

Cognitive Aging

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Synonyms

Lifespan development; Mental aging

Definition

As humans grow older, and particularly as they progress beyond the seventh decade of their life, there is typically an accompanying change in cognitive ability, often referred to as cognitive aging. As brains age, so do cognitive abilities such as memory, sensation, and attention decline. Cognitive aging can follow different trajectories, ranging from healthy aging to pathological aging. Many older people experience healthy aging, in which cognitive faculties are relatively well preserved and activities of daily living are not impaired. Others may experience some form of pathological aging, in which cognitive deterioration may significantly interfere with a person's ability to perform daily functions without assistance ("dementia"). Though "dementia" can result from many different underlying disorders, the most prevalent cause of dementia is Alzheimer's disease, accounting for about two thirds of all cases of dementia. In the gray area between healthy aging and dementia are individuals who are diagnosed with "mild cognitive impairment," suffering from a decline in cognitive function that is greater than what is expected to occur with healthy aging, but not sufficient to impair daily activities. Although not all do, many persons who are diagnosed with mild cognitive impairment go on to develop Alzheimer's disease later in life.

Research over the last several decades has emphasized that dementia is not an inevitable result of growing older; many adults age successfully and show only mild cognitive disruption. Much of the current research on cognitive aging, then, is aimed at elucidating what factors – both biological and environmental – separate those individuals who experience healthy aging from those who experience some form of pathological aging. This chapter will examine what cognitive functions change during normal, healthy aging, and which remain relatively unaffected by advancing age.

Theoretical Background

Some cognitive abilities are more susceptible to aging than others. Detailed memory for personal events, the ability to focus attention on relevant information, and the speed with which that information is processed are all particularly sensitive to cognitive aging and often show the most deterioration. Other domains, such as memory for factual knowledge and the processing of emotional material, are often relatively protected against the deleterious effects of aging. Although the different cognitive domains will be listed separately here, one should bear in mind that they are not independent of one another; for example, deficits in processing speed surely engender deficits in attention, and vice versa, and both of these can lead to deficiencies in memory.

Domains that Show Age-Related Decline

Memory for Personal Events

Memory for personal events – the who, what, when, and where of our lives; also referred to as "episodic" memory – typically shows some decline in healthy aging, and more severe decline in this domain is a well-known hallmark of dementia. Research on memory changes with aging has indicated that older adults have difficulty both at encoding new episodic information into memory and also at later retrieving that information. For example, when meeting someone for the first time, older adults may have difficulty encoding that their new acquaintance's name is "Ted." When they see Ted some time later, they may recognize him, but be unable to recall his name.

One proposed explanation for such impairment is that older adults have difficulty in employing strategies to associate one piece of information to another (as suggested by Fergus Craik 1986). Younger adults, for example, may think to themselves, "His hair is *red*, and his name is *Ted*," while older adults do not spontaneously utilize such strategies. This inability to bind together novel pieces of information can also explain why older adults tend to show little impairment in recognizing information as familiar, but experience greater difficulty when asked to recollect specific detail (e.g., "Yes, I recognize that man, but I can't recall his name or where we met.").

Attention to Relevant Information

Older adults tend to report difficulty in attending to relevant information, and disregarding information that is not related to their goals. For example, if out to dinner, older adults may find it more difficult than young adults to focus on a conversation with a dinner partner while ignoring the conversation at a neighboring table. The frontal lobe of the brain is known to orchestrate such activities as ignoring irrelevant information, and older adults typically perform worse than young adults on neuropsychological tests that measure frontal lobe function. On one such test, the Wisconsin Card Sorting Test, participants must match cards depicting objects that vary in shape, number, and color to other cards based on a rule that is secretly chosen by the experimenter. Participants must learn the rule by matching cards and receiving feedback on whether they have matched correctly or incorrectly. As the test progresses, the experimenter changes the rule, and the participant must adapt and learn the new rule. Compared to young adults, older adults show impairment in two aspects of the task: the ability to maintain a rule once it is learned (a deficiency of ▶ working memory), and the inability to abandon a learned rule once it has changed (an error of ▶ perseveration). Both of these errors arise, at least in part, from a relative inability to attend selectively to information that is relevant to the goal.

Processing Speed

One distinctive trait of aging is that older adults are slower than young adults. Older adults not only physically move slower than young adults, their cognitive ability is also slowed. On almost all timed laboratory tasks, older adults have slower reaction times than young adults. Luchies and colleagues (2002) have shown that this slowing of reaction speed becomes rapidly more pronounced after about 70 years of age. They have shown that the difference in speed between older and younger adults also becomes more evident as task complexity increases. This has lead to the conclusion that there are likely three factors that lead to older adults' apparent slowing: (1) slowing of motor performance due to degeneration in the nervous system, (2) slowing of communication between neurons in the brain, leading to slower processing of information, and (3) increased deliberation and caution when weighing different possible outcomes.

It is not just on tasks that measure reaction time that processing speed affects older adults' performance. Even on tasks that do not have a time constraint, older adults tend to perform worse than young adults if there are many pieces of information that must be kept in mind at once. For example, older adults show greater difficulty than young adults in solving mathematical word problems, when those word problems are read aloud to them. Importantly, when speed of processing is controlled for – when those same word problems are written out and people are given as much time as they need to solve them, for example – many of the age differences on such tasks are no longer observed. This indicates that older adults are not deficient in their math skill, for example, but rather are deficient in being able to maintain and update the multiple pieces of information that are relevant to solving the word problem.

Domains that Show Relative Age-Related Preservation

Knowledge for Facts

Although aging is typified by impaired memory for episodic details, memory for factual knowledge is relatively preserved across the lifespan. Healthy older adults tend to perform better than younger adults on tests of ▶ semantic knowledge, such as assessments of vocabulary, grammar, and general world knowledge (e.g., “Who was the 35th President?”). ▶ Procedural knowledge is also spared with aging; skills that have been used throughout the lifetime, such as job-related skills or musical training, are usually retained into older age. These types of retained knowledge are considered to be the basis for ▶ crystallized intelligence and expertise.

Emotion Regulation

The ability to regulate one’s reactions to emotional stimuli – calming oneself after seeing a snake, for example – is preserved as people age. Some researchers suggest that this ability actually improves with age, with older adults being able to direct attention away from negative experiences and to maintain positive experiences more effectively than younger adults. Older adults also tend to select more emotionally fulfilling activities to participate in than young people do, perhaps because older adults are more likely than young adults to prioritize social and emotional well-being (Carstensen et al. 1999).

Important Scientific Research and Open Questions

One of the open debates about cognitive aging is whether age-related cognitive deficits are domain-general or domain-specific. Domain-general theorists suggest that there is one specific deficit that underlies all of the age-related impairments. For example, Lynn Hasher and Rose Zacks (1988) have suggested that older adults’ cognitive impairments arise from a deficiency in inhibitory ability. Inhibition theory hypothesizes that older adults are less good than young adults at inhibiting thoughts and actions, and therefore have more difficulty appropriately deploying attention (and ignoring extraneous information). Older adults are therefore constantly juggling more information, which leads to memory and processing speed deficiencies. Other researchers have suggested that sensory deficiencies – such as loss of hearing and vision – underlie older adults’ impairment; if information is harder to process, then it becomes harder to select, maintain, update, and remember that information. Processing speed, as described earlier, is another domain-general explanation.

By contrast, other researchers believe that cognitive decline differentially affects specific aspects of cognition. Rather than the existence of a common thread that engenders all cognitive deficits, domain-specific theorists believe that age-related decline is specific to individual cognitive areas. For example, Naveh-Benjamin (2000) has suggested that older adults are specifically impaired in their ability to form associations between pieces of novel information. Such a hypothesis is supported by older adults’ relatively well-preserved recognition of information that is familiar, coupled with their frequent inability to recollect the context in which they learned that information. As noted earlier, older adults may easily recognize a new acquaintance, but they may fail to recollect his name or to recall where they met him.

Much research has also been done to investigate how older adults can compensate for these cognitive deficits. Yaakov Stern and colleagues (1994) have posited the notion of “cognitive reserve,” where environmental factors like advanced education and healthy lifestyles can be protective factors against neurodegeneration and cognitive function. It has also been suggested that healthy older adults recruit additional brain regions than young adults, to compensate for neural declines in other regions. Roberto Cabeza and others (2002) have used ▶ neuroimaging methods to show that younger adults often recruit brain structures on one side or another for various cognitive tasks (for example, recruiting the left, but not right, ▶ hippocampus when learning new information); healthy older adults, however, will often recruit structures bilaterally (for example, recruiting the hippocampus on both sides when learning new information).

Cross-References

▶ Emotional Regulation
▶ Human Cognitive Architecture
▶ Individual Differences in Learning
▶ Memory Dynamics
▶ Verbal Learning and Aging

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Cognitive and Affective Learning Strategies

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Synonyms

Learning skills; Self-regulated learning strategies; Self-regulatory processes; Study skills; Study strategies

Definition

A college student who prepares for an exam by summarizing the textbook chapters assigned by the course instructor, drawing a map of key concepts, monitoring his understanding while drawing the map, setting goals on a daily basis, and checking his progress against the goals uses a repertoire of learning strategies. When an elementary school student practices a poem by repeating the lines over and over again, researchers also refer to this behavior as a learning strategy. The term learning strategy denotes thoughts and behaviors the learner employs with the intention of acquiring knowledge and improving task performance (Weinstein and Mayer 1986). In line with this definition, learning strategies can be cognitive and affective. Cognitive learning strategies exert a direct influence on knowledge acquisition, whereas affective learning strategies facilitate learning via, for example, motivation and volition.

Learning strategies are to be placed at a medium level of granularity. They differ from learning styles, that is, general approaches to learning, a widely used distinction being that between deep level and surface level approaches to learning. A learning technique or tactic, such as underlining a keyword definition while studying a text, constitutes a smaller unit of thought or behavior than a learning strategy. Hence, learning strategies can be understood as collections of learning techniques orchestrated by the learner.

Learning strategies are central to models of self-regulated learning and some researchers equate skilled execution of learning strategies with self-regulated learning. Self-regulated or strategic learners are assumed to have knowledge of various learning strategies, employ appropriate strategies in order to attain their learning goals, and flexibly adapt their choice of strategies to the task and context they face.

Theoretical Background

The role of the learner's deliberate thought processes and strategic behaviors in bringing about learning outcomes began to be investigated in the 1960s as a result of the fundamental paradigm shift in cognitive and educational psychology. As the behaviorist view of learning as a strengthening of responses to stimuli by means of rewards became replaced by the cognitive view of learning as information processing, researchers turned their attention to basic cognitive learning strategies, particularly mnemonic strategies. But it was not until the emergence of the constructivist paradigm in psychology and education that researchers focused on complex learning strategies. At the heart of constructivism is the view of learning as active information processing: The learner actively selects and organizes to-be-learned information in working memory and integrates new information with information stored in long-term memory. This view of the learner as a sense maker entails the assumption that the learner employs cognitive learning strategies that are more complex than, for example, mnemonic strategies (Mayer 1996).

There are a number of taxonomies or systems for categorizing learning strategies. The broad distinction between primary strategies (aimed at cognitive processing) and support (or affective) strategies is widely recognized and accommodates the finding that learners who have a repertoire of cognitive learning strategies may not succeed in achieving certain learning outcomes. Both *skill* (the ability to select appropriate cognitive learning strategies and execute them successfully) and *will* (the motivational and volitional requirements for effective strategy use) are necessary.

In their well-known taxonomy of learning strategies, Weinstein and Mayer (1986) distinguished six types of cognitive learning strategies: rehearsal strategies for basic and complex learning tasks, elaboration strategies for basic and complex learning tasks, and organizational strategies for basic and complex learning tasks. Hence, Weinstein and Mayer considered both the specific functions of learning strategies with regard to information processing as well as differences in the complexity of learning tasks. Rehearsal strategies, such as mentally reciting keyword definitions, serve the cognitive functions of selection (transfer of new information into working memory) and acquisition (transfer into long-term memory). The cognitive functions of elaboration strategies are construction and integration. According to Weinstein and Mayer, the learner constructs connections between pieces of new information or integrates new information with prior knowledge when generating elaborations, such as mental images or analogies. Today, most researchers define only the latter process, that is, the construction of connections between new information and prior knowledge, as elaboration. Organizational strategies, the remaining type of cognitive learning strategies in the Weinstein and Mayer taxonomy, are directed at the construction of internal connections within new information. Outlining a textbook chapter is an example of an organizational strategy. In addition to cognitive learning strategies, Weinstein and Mayer included affective strategies and comprehension monitoring strategies in their taxonomy of learning strategies.

Self-monitoring of comprehension during learning constitutes a metacognitive learning strategy. Metacognitive learning strategies also include planning and reflection. Models of self-regulated learning stress the importance of metacognitive activities during learning and there is ample evidence that these activities indeed contribute to learning. However, cognitive and metacognitive learning strategies are very much intertwined as metacognitive strategies operate on domain knowledge. Therefore, the effectiveness of employing metacognitive learning strategies when they do not form part of a well-orchestrated repertoire of cognitive learning strategies has to be considered small.

Support strategies or affective learning strategies exert an indirect influence on cognitive processing. When learners employ affective learning strategies they aim at setting a positive mood for learning, arranging the environment to be suitable for studying, managing internal and external resources such as concentration and time, and coping with anxiety and other emotions about learning. The focus of research on affective learning strategies has not been, however, on the strategies just described but on strategies targeting motivation and volition. Motivational learning strategies include, for example, goal setting strategies and strategies for sustaining academic self-efficacy. The learner employs volitional learning strategies to form intentions and maintain commitment toward learning goals, particularly in the face of competing non-academic tasks and activities. The focus on motivational and volitional learning strategies might stem from research providing insights into the major difficulties experienced by self-regulated learners. One of these difficulties is procrastination. It has been conceptualized as a failure to exert volitional control over one's own learning, meaning procrastinators fail to employ appropriate strategies for managing their commitment toward learning goals.

Important Scientific Research and Open Questions

Empirical research on cognitive and affective learning strategies has centered on the development of strategic learning and on the training of learning strategies. Research indicates that strategy use increases with age and that the development of strategic learning follows a trajectory from rudimentary, sporadic strategy use to appropriate, consistent strategy use. When trained or prompted young children benefit from and can acquire cognitive and metacognitive learning strategies even before they enter the elementary grades. In the secondary grades, learners enlarge their repertoire of learning strategies and eventually have sophisticated cognitive and metacognitive learning strategies at their disposal (e.g., Zimmerman and Martinez-Pons 1990). However, several deficiencies regarding the acquisition and use of learning strategies have been identified and some of them have been linked to developmental processes. Young children have been demonstrated to have a mediation deficiency (Flavell et al. 1966), which refers to executing a cognitive or metacognitive learning strategy in an inadequate or incomplete way and hence failing to benefit from it. Learners who show a mediation deficiency are at a cognitive developmental level that does not permit them to construct the cognitive "mediators" required for adequate and full execution of the learning strategy. In other cases, learners show production deficiencies (Flavell et al. 1966): Although they may spontaneously produce appropriate cognitive and metacognitive learning strategies, they typically fail to do so. In yet other cases, learners at the secondary and college levels fail to benefit from their use of cognitive and metacognitive learning strategies although they spontaneously produce appropriate strategies. It has been suggested that utilization deficiencies (Miller 1994) underlie the failure to benefit from the use of cognitive and metacognitive learning strategies once the learner has completed the developmental trajectory for a specific strategy. Which factors contribute to the occurrence of utilization deficiencies is not yet completely understood. Among the causal mechanisms discussed are high cognitive load during initial strategy use, insufficient metacognitive self-regulation, low perceived self-efficacy and cognitive developmental factors, particularly working-memory capacity limitations during childhood.

At the most general level, learning strategy interventions differ in how they promote effective strategy use. Learning strategies can be trained directly through explicit instruction on the cognitive, metacognitive, and affective components of strategic learning. But they can also be trained indirectly in learning environments that facilitate or require strategic learning. Some researchers argue that it may be most productive to combine elements of direct and indirect interventions to promote the acquisition of learning strategies. However, the appropriate balance of explicit instruction and implicit facilitation has yet to be established through empirical studies.

Numerous studies on direct interventions are reported in the learning strategies literature. Altogether, these studies show that direct interventions are effective when they are carried out over an extended period of time, provide the learner with information about when to use which learning strategy, and include instruction on metacognitive strategies, that is, planning, self-monitoring, and control strategies. Most direct interventions target reading, writing, mathematical problem solving, or foreign language learning. One of the best known direct interventions is reciprocal teaching (Palinscar and Brown 1984). Reciprocal teaching was designed to facilitate the acquisition and transfer of reading comprehension strategies in the regular classroom. During reciprocal teaching, students read a text passage by passage and take turns in executing a sequence of cognitive and metacognitive learning strategies: asking questions, summarizing, seeking clarification, and making predictions. The teacher models and scaffolds the use of each strategy, fading his/her support as students gain proficiency in executing the strategies. The effectiveness of reciprocal teaching has been established in field and laboratory studies. Reciprocal teaching produces short-term and long-term effects on measures of comprehension, strategy knowledge and skills, and transfer to novel tasks.

The implementation of learning journals as an adjunct to classroom instruction at the secondary level or as a supplement to traditional college coursework forms an example of an indirect learning strategy intervention. The learning journal constitutes a specific writing task that requires students to organize, elaborate, and reflect on learning contents, typically over an extended period of time (Nückles et al. 2009). It has been demonstrated to produce learning gains and to promote the acquisition of cognitive and metacognitive learning strategies. For the potential benefits of learning journals to unfold, however, instructional support appears necessary. Such support can be provided, for example, through strategy prompts embedded in the writing instruction. The ineffectiveness of learning journals written without instructional support, which emerged in early studies, seemed to confirm concerns about indirect learning strategy interventions that had been raised since the early decades of research on learning strategies (e.g., Weinstein and Mayer 1986). However, powerful evidence of the effectiveness of guided journal writing has weakened these concerns.

At the conceptual level, a central issue of debate among researchers is the nature of strategic learning. Underlying the taxonomy of learning strategies, the developmental model and the training approaches outlined above is the assumption that skill and will, that is, relatively stable learner characteristics, underlie the use of learning strategies. Several researchers have argued, however, that the nature of strategic learning has to be conceptualized differently. Two alternative but reconcilable conceptualizations for strategic learning have been proposed. First, drawing on empirical studies showing small if any relationships between learners' self-reported, habitual strategy use and achievement measures, researchers have suggested to conceptualize the use of learning strategies as situational and not as dispositional. Accordingly, learning strategies would have to be understood as strategic actions that are specific to the respective task and context faced by the learner. Second, based largely on the same evidence, other researchers have advanced the notion of preferences (and not competence or aptitude) underlying the use of learning strategies. Recent efforts to resolve conceptual and methodological issues on self-regulated learning, particularly the refinement of on-line trace methodologies, might help to bring about more clarity on the nature of strategic learning in the future.

Cross-References

► Elaboration Effects on Learning
► Elaboration Strategies and Human Resources Development
► Learning Styles
► Metacognition and Learning
► Self-Regulated Learning
► Self-Regulation and Motivation Strategies

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Cognitive and Noncognitive Processes

► Creativity, Problem Solving, and Feeling

Cognitive Anthropology

► Anthropology of Learning and Cognition

Cognitive Apprenticeship

► Situated Learning

Cognitive Apprenticeship Learning

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Synonyms

Reciprocal teaching; Scaffolding; Situated cognition; Situated learning

Definition

Cognitive apprenticeship learning is situated within social constructivist approaches to instruction. It prioritizes the use of authentic tasks and situations, and the role of interactions between more and less skilled individuals in order to foster the development of metacognitive strategies and domain-specific problem-solving skills. A focus on cognitive rather than physical skill development and the use of planned rather than entirely naturalistic opportunities for skill development and practice differentiate cognitive apprenticeship from more traditional models of craft apprenticeship.

A key process goal of cognitive apprenticeships is to make otherwise tacit cognitive and metacognitive processes explicitly available during the performance of complex tasks. This is done via the instructor serving as an expert and coach who models and verbalizes their thought process as well as supporting increasingly independent and reflective practice of these same processes by the learner. Specifically, according to Collins et al. (1987), the instructor uses the timely implementation of three instructional methods designed to facilitate the acquisition of skills (modeling, coaching, and scaffolding), two methods designed to improve the clarity of observation and self-observation (articulation and reflection), and one method designed to promote learner autonomy (exploration). These methods are grounded in social learning theory because learners observe, enact, and respond to feedback. Cognitive apprenticeship techniques make use of scaffolding, which allows students to perform at a higher level than they would otherwise be able to if acting alone because of the instructor's accuracy in monitoring and diagnosing each student's current ability level. These methods broadly align with research on the contextually situated nature of expertise, in part because enculturation into an expert community is adopted as an implicit instructional goal. Finally, these methods draw upon stage-based descriptions of skill acquisition in which the goal is for the learner to be able to execute their skills automatically and in a wide variety of appropriate contexts.

Theoretical Background

Within a professional domain, experts display the ability to identify and solve problems because they possess a substantial body of interconnected conceptual knowledge and accessible procedural heuristics or decision-making strategies (Collins et al. 1987). Experts also have a wealth of cognitive and metacognitive knowledge and strategies at their disposal, but the seemingly effortless execution of these strategies often renders the complex constituents of these processes invisible to the novice learner (Mayer 1991). Proponents of cognitive apprenticeship learning have argued that traditional schooling reduces the opportunity to observe and emulate authentic problem solving, isolates the presentation and use of information from the contexts in which it will be relevant, and masks expert-like thought processes from novice learners (Brown et al. 1989). Thus, it does not foster the type of contextually embedded practice of authentic skills that supports the development of expertise and, instead, limits the development of content mastery and undermines intrinsic motivation. Apprenticeships offer opportunities for the learner to engage in meaningful and contextualized practice of transferable knowledge and skills (Collins et al. 1987). Accordingly, not only is domain knowledge viewed as epistemologically inseparable from the context in which it will be used, but on a practical level, it must be acquired within contextualized instructional experiences in order to be available during problems requiring generalization and transfer.

Cognitive apprenticeship differs from traditional instruction in two key ways. First, its social constructivist foundation incorporates a view of meaning as something that is negotiated and developed among individuals who reside within a community. Dialogic interactions between teachers and students are thus essential to the learning process. All are expected to be actively engaged in discovering, articulating, modeling, and refining conceptions of the content as well as the conditions under which that content can be meaningfully used and how such conclusions came about. Second, cognitive apprenticeship learning involves the practice of authentic tasks instead of isolated component skills. The role of the teacher thus becomes one of coach and facilitator, whose job is to assist students as they interact with complex and meaningful problems – first through modeling, then scaffolding, then prompted reflection. Thus, learners move toward more expert-like performance because they have the chance to observe, discuss, and receive feedback on their use of strategies. They acquire flexible, task-oriented problem-solving strategies, and become more articulate about their strategy use because of an increased ability to reflect meaningfully on the learning process itself.

Cognitive apprenticeship is possible because of several key psychological concepts. One, articulated by Bandura (1977) through his social learning theory, is the idea that humans have a tremendous capacity to learn through the actions and verbalizations of another person. Bandura called this person a model, and thus, the term "modeling" was adopted to refer to cognitive and behavioral displays meant to teach another person. In cognitive apprenticeship, the teacher serves as the initial model, but as students progress, they are encouraged to adopt this role for one another. A second key concept is the process of scaffolding (Vygotsky 1978). In scaffolding, a more skilled person provides assistance to allow a less skilled individual the opportunity to perform at a level that he or she could not do alone. The facilitator ensures the maintenance of a zone of proximal development, a conceptual space through which the learner progresses as skills are developed. Scaffolding processes include verbal and physical prompts such as questions during expository text reading, or cue cards for presented during composition processes. Scaffolding also includes the joint completion of task components which cannot be achieved independently. In combining these concepts of modeling and scaffolding, cognitive apprenticeship calls upon the teacher to simultaneously model expert-like skills and provide appropriate scaffolds during each stage of the learning process. A third important concept is the important role played by metacognitive strategies in domain expertise. In addition to declarative, procedural, and conditional knowledge, experts possess a significant capacity to recognize patterns, connect problem states with solution paths, and execute strategies that yield solutions (Mayer 1991). The novice learner therefore benefits from metacognitive reflection by the expert who is modeling the skill in order to learn the conditions under which particular strategies are used and how troubleshooting may occur. This allows the novice to understand how and why problems are framed, approached, and solved. Thus, the expert thinks out loud and uses appropriate prompting techniques within a collaborative dialogue in which options for solving a problem or completing a task are explicitly verbalized. In application, this may mean that the teacher models how to generate appropriate "why" questions while reading, how to revise the first draft of an essay, and how to dissect math problems into givens and unknowns.

Alongside this argument for the benefits of a situated learning approach, Collins et al. (1987) presented a framework for cognitive apprenticeship learning that included six processes teachers use to promote student learning. During learning episodes which are carefully sequenced for increasing complexity and diversity of required skill, the following take place:

1. *Modeling*: In modeling, the expert carries out a task or solves a problem. This is done in such a way that students can observe the required steps, but also can listen to the control processes and decisions that the expert uses along the way.
2. *Coaching*: In coaching, students are provided with prompts, feedback, and other reminders pertinent to the successful completion of a specific task.
3. *Scaffolding*: In scaffolding, teachers provide physical and verbal prompts and support but only to the degree that the teacher completes parts of the task which the students cannot autonomously attempt. As skill levels increase, supports are removed through the process of fading.
4. *Articulation*: In articulation, teachers prompt students to explicitly state their approaches and strategies, and to characterize their beliefs about the domain or skill.
5. *Reflection*: In reflection, a reflection on process is permitted via analysis of recent performance. This can take place via verbal review or by reviewing a recording.
6. *Exploration*: In exploration, students are encouraged to seek and define new problems within the domain, in order to practice using and transferring skills from one context to another.

Important Scientific Research and Open Questions

Initially, the cognitive apprenticeship approach was identified in programs designed to improve reading comprehension, writing, and mathematics skills. Collins et al. (1987) describe these techniques in detail. They are reciprocal teaching (Palinscar and Brown 1984), procedural facilitation of writing (Bereiter and Scardamalia 1987), and Schoenfeld's (1994) approach to teaching mathematical problem solving. Of these, reciprocal teaching has garnered the most empirical attention. Employed in elementary, middle, and high school settings, reciprocal teaching is a reading comprehension strategy instruction method where teachers and students alternate between reading and then discussing the content and the metacognitive processes required to comprehend the text. Working in small groups, teachers and students take turns to lead the discussion. Scaffolding and prompting takes place as necessary, and over time, the goal is to fade the usage of such prompts due to the increasingly expert-like nature of the students' reading strategies.

In their seminal research, Palinscar and Brown (1984, study 1) used reciprocal teaching techniques in a group of seventh grade students with poor comprehension skills. Comparison groups received instruction on how to locate information during testing, or participated in the testing schedule but received no additional instruction. After the intervention, comprehension accuracy increased from 30% to 80% for the experimental group, who also performed at or above grade level on measures of skill generalization and transfer. Dialogue analyses showed that as time went on, more expert-like questioning and summarization strategies were used by the experimental group. These results have been replicated – in a review of 16 quantitative studies of reciprocal teaching, Rosenshine and Meister (1994) reported a median effect size of 0.32 and 0.88 for standardized and experimenter-developed comprehension tests, respectively. However, in a qualitative analysis assessing the success of adopting reciprocal teaching methods, Hacker and Tenent (2002) reported that teachers encountered difficulties in ensuring that groups of students stayed on-task, used strategies effectively, and generated sufficiently interrogative questions. Enduring challenges of adopting cognitive apprenticeship models may therefore be how to balance classroom logistics and developmental needs in the absence of low student-to-teacher ratios, and how to effectively train teachers to become flexible in their implementation of apprenticeship-liked teaching strategies.

Other examples of cognitive apprenticeship techniques can be found in areas such as science and scientific inquiry (Roth and Bowen 1995), instructional technology, computer programming, teacher professional development, medicine, and psychology (Järvelä 1996). Each emphasizes qualities of situated learning that map onto cognitive apprenticeship, such as learning in a social context through the joint consideration of ill-defined problems, and the importance of drawing upon the knowledge of peers or instructors who demonstrate higher levels of expertise (Roth and Bowen 1995). However, in a review, Järvelä (1996) identified several areas that would benefit from additional research. She criticized proponents of cognitive apprenticeship for making assumptions about the ubiquitous presence of the type of social interaction required for successful apprenticeship-based lessons. Cognitive apprenticeship models often assume that learners are able and willing to engage in extensive collaborative discussion in which their inner thought processes can be articulated. Järvelä identified the need to investigate the process of individualizing instruction, since scaffolding and modeling often need to be adjusted to suit the needs of linguistically, motivationally, and socially diverse learners.

Along similar lines, relatively little emphasis has been placed on gathering data to measure the moment-by-moment interactions among students and between students and teachers. It is important to understand how the process of apprenticeship, as revealed through small group processes, leads to the achievements documented in many studies. This may require mixed methods research that can connect intra-individual, inter-individual, and contextual variables with learning outcomes. In addition, research is needed to document the long-term feasibility and success of classrooms that adopt cognitive apprenticeship methods, whether these are defined from a teacher, learner, or administrative perspective. Finally, questions have been raised about the legitimacy of the claim that tasks used to teach within apprenticeship-based lessons are truly authentic, as well as the context and conditions in which cognitive apprenticeship techniques are most appropriate and feasible. Apprenticeship approaches seems to be most successful in content domains where a metacognitive or self-regulatory process lies at the heart of what needs to be learned, and where problem solving is integral to the desired skill. This is the case even when the tasks presented cannot always be considered to be entirely authentic. But when students must undergo radical cognitive restructuring as well as domain-related skill development, such as in the case of conceptual change in science, apprenticeship models may prove to be less successful (Vosniadou 2007).

Cross-References

► Apprenticeship-Based Learning in Production Schools
► Scaffolding
► Self-regulated Learning
► Situated Learning
► Socio-constructivist Models of Learning

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Cognitive Apprenticeship Modeling

► Expert Cognitive Modeling and Problem-Based Learning

Cognitive Approach

► Situated Cognition

Cognitive Architecture

A theory, expressed as a suite of computer programs that provides specification for structures and related processes of the cognitive system. Models derived from the architecture are typically used to explain phenomena in several domains.

Cross-References

► Schema-Based Architectures of Machine Learning

Cognitive Artifacts and Developmental Learning in a Humanoid Robot

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Synonyms

Artificial intelligence; Educating robots, teaching robots as humans; Human-aided machine learning; Human-robot social interactions

Definition

Development Learning in a humanoid robot defines an incremental, staged methodology for machine learning based on similar principles that guide children's development. It is therefore strongly tied to developmental psychology, according to the epigenetic principle: as each stage progresses, it establishes the foundation for the next stages. Cognitive Artifacts are a humanoid robot's (and a child's) learning aids – or cognitive enhancers – such as books, toys, puzzles, drawing boards, or construction bricks, employed by a caregiver in order to guide development learning of a humanoid robot. They are an important tool to achieve socially intelligent humanoid robots (Arsenio 2004a, b) – introducing robots into our society and treating them as us – using child development as a metaphor for developmental learning of a humanoid robot.

Theoretical Background

Research on Development Learning for a humanoid robot has been gaining momentum as several research groups argue that this is an essential strategy in order for the robot to achieve eventually human-level cognitive capabilities. As such, scientists have claimed for the usage of Cognitive Artifacts by a human caregiver in order to teach the robot as a child.

Turing, the creator of the famous Turing test to evaluate artificial intelligence of computers, suggested that, instead of producing programs to simulate the adult mind, we should rather develop one which simulates the child's mind. He also suggested that an appropriate course of education would lead to the adult brain.

Infants develop both functionally and physically as they grow. Such development is very important for infants' learning. Evidence suggests that infants have several preferences and capabilities shortly after birth. Such predispositions may be innate or pre-acquired in the mother's womb. Inspired by infants' innate or pre-acquired capabilities, the robot is initially preprogrammed for the detection of real-world stimulus. These preferences correspond to the initial robot's capabilities (similar to the information stored on human genes – the genotype) programmed into the robot to process these events. Starting from this set of premises, the robot should be able to incrementally build a knowledge database and extrapolate this knowledge to different problem domains (the social, emotional, cultural, developmental learning will set the basis for the phenotype). For instance, the robot learns the representation of a geometric shape from a book (Arsenio 2004b), and is thereafter able to identify animate gestures or world structures with such a shape. Or the robot learns from a human how to poke an object, and uses afterwards such knowledge to poke objects to extract their visual appearance (Fitzpatrick 2003). Robots can therefore boost their learning capabilities both by acting on the environment or by observing other person's actions.

In contingency learning, the simple contingent presence of the caregiver and the objects involved in the action provide the necessary cues for an infant to learn. In the field of robot learning, it is often equated to reinforcement learning. The robot Kismet (Breazeal and Aryananda 2000) relied heavily on caregivers to socially transfer abilities to the robot (as they do to infants) by means of scaffolding. The term scaffolding as introduced by Vygotsky refers to guidance provided by adults that helps a child (or a humanoid robot) to meet the demands of a complex task. The goal is to increase the chance of a robot succeeding by making the task of learning something about the world a little easier in some way. Examples of scaffolding includes the reduction of distractions and the description of a task's most important attributes, before the robot (or an infant) is cognitively apt to do it by itself.

Important Scientific Research and Open Questions

Several research fields have been interested in developmental learning for robots besides engineers and computer scientists, such as psychologists, philosophers, neuroscientists, anthropologists, biologists, among others.

Previous approaches for transferring skills from human to robots rely heavily on human gesture recognition, or haptic interfaces for detecting human motion. Environments are often oversimplified to facilitate the perception of the task sequence. Other approaches based on human–robot interactions consist of visually identifying simple guiding actions (such as direction following, or collision), for which the structure and the goal of the task are well known.

Teaching robots as if they were babies exploiting humans as caregivers has been the focus of research work by (Metta et al. 2000; Kozima and Yano 2001; Breazeal and Aryananda 2000; Fitzpatrick 2003; Arsenio 2004a, b). Learning from Demonstration is also one approach employed for developing incrementally cognitive capabilities on a humanoid robot. This strategy has been used for a robot to learn autonomously information about unknown objects (Fitzpatrick 2003; Arsenio 2004a), employing strategies that include simple actions such as grabbing or poking an object to learn its underlying structure. Learning aids, such as books, were also used as another source of information that can be transmitted to a robot through a human (Arsenio 2004b).

Through social interactions of Cog – a humanoid robot at MIT – with an instructor, the latter facilitates robot's perception and learning in the same way as human teachers facilitate children's perception and learning during child development phases. The robot will then be able to further develop its action competencies, to learn more about objects, and to act on them using simple actions such as shaking (Fitzpatrick 2003; Arsenio 2004a). These works show how object recognition and robot experimental manipulation evolve developmentally from human demonstration. By transferring the manipulation skill from human to robot, the latter can generate equally training data to the object recognition algorithm. For instance, (Arsenio 2004a) shows that by having the robot hammering on a table, the perceptual system extracts visual templates of the object which is thereafter recognized as the same object previously segmented from human demonstration.

Indeed, a large range of applications were investigated in which the humanoid robot Cog was taught as a child by a human caregiver, exploiting human–robot interactions for emulating cognitive capabilities on the robot. Such development was inspired both by Vygotsky and Margaret Mahler's child developmental theories, with several developmental milestones, as predicted by Mahler's theory, implemented on Cog (Arsenio 2004a).

Cross-References

► Cognitive and Affective Learning Strategies
► Cognitive Learning
► Cognitive Robotics
► Developmental Cognitive Neuroscience and Learning
► Developmental Robotics
► Human–Robot Interaction

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Cognitive Artifacts, Technology, and Physics Learning

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Synonyms

Concrete–abstract objects and cognition; Imagined worlds; Worlds from ideas

Definition

Certain types of computer software are powerful *cognitive artifacts* (Norman 1991). A cognitive artifact is a tool to enhance *cognition*, allowing the user to create and explore "concrete–abstract objects" and "worlds from ideas" and check how well these "worlds" can correspond to "real worlds," or make sense of "imagined worlds." Cognitive artifacts can become an essential tool in teaching and learning in physics education, making learning of complex abstract concepts and models more significative and epistemologically grounded.

What I cannot create I cannot understand (text found on Richard Feynman's blackboard at the time of his death).

Theoretical Background

Learning Physics, Conceptual Difficulties, Familiarization, and Reification

Physics is a relatively new subject in the secondary curriculum. Only in the second half of the nineteenth century did science education become part of the curriculum, and only in the second half of the twentieth century did physics, or physics and chemistry, commonly become an autonomous subject in the developed countries.

Teaching and learning physics has always been considered a difficult task by most teachers and students (see, e.g., Reif 2008). However, for Richard Feynman (1918–1988), a famous physicist and Nobel Prize winner, "subjects like philosophy and psychology are hard, but physics is easy and that's precisely why we know so much about it." But if physics is "easy," why is it difficult to teach and learn? Certainly, there are many reasons for that. One, surely not the least important, is that teachers soon face the harsh reality of how deep and extensive their students' difficulties are and how naïve it is to assume that kids are just as enthusiastic about the curriculum as they are.

Besides the many social-cultural problems teachers face in their teaching, it can be argued that learning science, and physics in particular, is like learning a new language – a language that uses many of the same words as ordinary language but with altered and far more precise meanings.

The essence of the problem of learning the language of physics is learning to make conceptual distinctions among related but distinct concepts. It is, essentially, a matter of *familiarization* with the lexicon of the language and its proper use in specific contexts. *Familiarization* is an important issue when learning science (and mathematics). And, for some eminent scientists, *becoming familiar with* is so important to the success of scientific ideas that new ideas only become triumphant because supporters of old ideas die, as Planck wrote in his autobiography (Planck 1950, pp. 33–34): "A new scientific truth does not triumph by converting its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it." Scientists frequently say that they do not understand some of the most fundamental concepts or theories in their own field. For example, Feynman confessed that he did not really understand quantum mechanics.

Experienced physics teachers also alert us to the fragile nature of our understanding. For example, many of the useful concepts of physics are, for teenagers, mysterious and difficult to grasp; the nature of an electrostatic charge, of a magnetic field, of electromagnetic wave propagation in vacuum, or of charm and color of quarks are examples. There is no absolute understanding or knowledge of the nature of these entities, yet any young adult will certainly wonder about their nature. In physics education, there is surely the need for the kind of humility shown by Feynman, when he felt he did not fully understand quantum mechanics. As Davies wrote (1997, pp. 420–421):

> ▸ If teachers continue to give the impression that they do have a better basic understanding of such fundamentals than their students, the students will see their own perplexity and uncertainty as a negative reflection on their own capabilities. Even in this group today there will be some of you who will remember the relief you felt when you could use some equation, and your mathematics, to answer a problem, rather than stay with your uncertainties regarding the concepts involved. We learn and teach others to use mathematics to manipulate the symbols associated with mysteries. This does not mean that we or they have a grasp of the mysteries themselves.

Physics deals with conceptual objects such as *force, velocity, energy, radiation*, etc. These are all words that are in common use in everyday language. In fact, many people will use words like momentum, force, and energy interchangeably in casual conversation. Nonetheless, in physics these concepts and the words we use to name these concepts are quite distinct. *Force*, in the language of physics, is the "rate of change of momentum." Energy or work can be related to force as can momentum, but neither force nor momentum is conceptually the same as energy. Power is yet a different concept.

Another important issue in learning such abstract concepts, and one that is intimately related to familiarization, is the issue of *reification*, that is, of *concretization of abstract objects*. According to Wright and Wright (1998, p. 128), "Reification is a central goal [... of learning science and mathematics]; it essentially defines scientific literacy. It is the foundation for common sense about how the world works (...)."

If we take the position that *reification* and *familiarization* are essential aspects of learning physics and mathematics, we are led to ask how can such learning be improved with technology and, specifically, with computers? Hebenstreit, writing about the role of computers in education, coined a term that provides an important insight into understanding how computers can help in the reification of knowledge. For Hebenstreit, computers allow us to manipulate a new type of object; a kind of object that he calls a *concrete–abstract* object (Hebenstreit 1987). *Concrete* in the sense that they can be manipulated on the screen and react as "real objects" and *abstract* because they might be physical or mathematical constructs such as vectors, equations, fields, etc.

Teachers tend to teach what they can teach, not necessarily what they think it would be useful to teach. This is what some authors call *technological determinism*. For example, most of the practical and theoretical teaching is dependent on the *limited* mathematics that students (and also teachers) can use: *simple analytical tools* that often need complex algebraic manipulation. But with computer tools, one can use *numerical approaches* that can turn out to be simpler than analytical ones and lead to improved familiarization and reification of physics by students.

A characteristic feature of using a computer as a cognitive artifact is that the emphasis is on *meaning* and *semiquantitative reasoning* instead of formulaic solving of well-classified problem types. A good example of what is semiquantitative reasoning can be done with a mathematical object such as $dx/dt = 4 \times t$. (For the sake of concreteness, assume that x is a distance and t is a time – in that case the 4 represents an acceleration.) What does this tell us? First, the rate of change of x is proportional to t and that means that the larger the value of t the larger the rate of change of x. More precisely, when t is 5 time units, for example, the rate of change will be, at that instant, $4 \times 5 = 20$ velocity units. If t is 10 time units, then the rate of change will be $4 \times 10 = 40$ velocity units. That is, if t doubles, the rate of change of distance doubles. Moreover, x always increases for positive values of t. Consider another example: $dx/dt = 4 \times x$. (NB in this case the 4 represents 1 divided by a time or a frequency.) Now we have a rate of change of x that is proportional to x at any instant of time. For example, if x is zero, then the rate is also zero. For a positive value of x, at any instant of time, the rate of change is positive and so x increases. Experts can readily do this kind of semiquantitative reasoning even if they do not know the specific details of a calculation.

Physics is a science in which visualization plays an important role, even when visualization is only used to show mathematical objects, such as vectors or field lines. It therefore seems reasonable to suppose that computer visualization can help learners create meaning from manipulations of abstract objects. This capability of the computer has been used extensively in many contexts and is stressed by many authors, who pointed out to the capability of making dynamic representations of non-concrete formal objects. This ability accounts, at least in part, for the increasing importance of computer visualization and simulation in science in general and in physics in particular. Galison (1997), for example, wrote about the new "epistemic position" of computers and simulations in the production of physics knowledge.

Nickerson (1995) pointed out that researchers had not focused on students as authors of simulations. He argued that "it is only difficult, not impossible, and the work that goes into the successful building of a microworld is likely to deepen one's understanding of whatever the microworld is intended to simulate" (p. 16). To build simulations, one can use programming languages, but these often require technical knowledge and skill outside of the domain being simulated. This is the reason why Nickerson proposed the development of specific tools that can be used by people without that knowledge (p. 16): "For student-developed simulations to be practical for educational purposes, it will probably be necessary to develop tools that are designated to facilitate the building of simulations by people without such language facility and programming experience." Such tools have been developed in the last decade (see, e.g., Teodoro 2003), and its impact has been assessed (see, e.g., Teodoro and Neves 2011). These tools have been used extensively as an "integral part" of new curricula, such as *Advancing Physics*, developed by the Institute of Physics in the UK (2000/2008).

In the early 1980s, it was not clear how important and ubiquitous computers would become in our society. Now computers have changed working practices and leisure activities, and everybody agrees that using computers is part of literacy and numeracy. The impact on science is so profound that, for the National Research Council (USA), scientific computation can be considered a third fundamental methodology of science – parallel to the experimental and theoretical approaches.

It has been pointed out that computers, like all technological innovations in schools, tend to follow a cycle of high expectations, rhetoric about the need to innovate, oriented policy and finally limited use. There have been many promises of radical change in education from technology enthusiasts. After intelligent tutoring systems, multimedia, Internet, etc., educators have become cautious of what can really make a difference. Educators increasingly tend to focus on supportive systems, on coaching and scaffolding. Groups such as the group that worked with the Education Technology Center in Harvard between 1985 and 1995 have initiated this perspective. The Harvard perspective was based on four principles (Harvard Educational Technology Center 1988):

Goals: Focus on key concepts and on the overall nature of knowledge, evidence, and inquiry in a discipline.

Teaching Approaches: Help students develop a deep understanding of the subjects they study by taking into account their prior theories and by integrating teacher-directed instruction with opportunities and challenges for critical inquiry.

Technology: Use technologies selectivity to make a distinct contribution to teaching and learning, for example, to present dynamic models of key ideas or to enable students to participate in disciplined inquiry.

Implementation: Design technology-enhanced teaching modules and approaches that can be gradually and gracefully integrated into existing curriculum and practice.

As we can see in these statements, *technology is not a goal in itself* but a selective contribution "to make a distinct contribution to teaching and learning." And it is the *teacher* that really can make the difference in creating powerful educational environments *with* technology.

Important Scientific Research and Open Questions

Embedding the use of computers as information delivery tools has been done in schools in the last decade. This use usually adds nothing fundamentally different from previous tools of delivering information. But integrating computers as powerful cognitive tools in the physics curriculum (as well as in mathematics and other scientific subjects) is a much more difficult endeavor. It needs a coherent view of the role of cognitive tools, a culture of teaching and learning close to the way science is done, and reasonable organizational conditions.

A properly balanced integration of computer cognitive tools in the curriculum remains to be found. Important open questions left for future research are, for example: Is there an optimal set of tools that minimizes cognitive opacity? If a course is organized into lectures, practical and laboratory work, what is the best way to integrate computer cognitive tools? How do these tools relate with interactive digital documents?

We are beyond the point of needing short-term programs that assume that innovation is guaranteed because it has proven to work with enthusiastic adopters. We need programs that encourage cumulative improvement committed to ongoing slow but clear change. Computer tools and computer networks have an enormous potential impact in learning, and it will increase as technology advances. But, as Seymour Papert pointed out 30 years ago, *there is a world of difference between what computers can do and what society will choose to do with them*. We all face the challenge of using technology to empower learning (as well as other human activities), and not to create a kind of Aldous Huxley *Brave New World* where machines control everything, dehumanizing schools and learning.

Cross-References

► Cognitive Artifacts and Developmental Learning in a Humanoid Robot
► Learning Through Artifacts in Engineering Education
► Models and Modeling in Science Learning

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Cognitive Aspects of Deception

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Synonyms

Intentional deception; Tactical deception

Definition

At the *behavioral level*, deception constitutes the misinterpretation of situations by one individual as a consequence of the behavior or signals of the other individual. Functionally, such a misinterpretation poses costs to the receiver and benefits the deceiver.

This operational concept refers to a variety of responses ranging from species-typical patterns given in a certain context, like the feigning of injury by ground-nesting birds or the false alarm calls of sentinel birds in mixed species foraging flocks, to a broad range of diverse behavioral patterns which are used very flexibly in different situations. The term "tactical" deception has been introduced to emphasize a contrast between short-term tactics (in which the deception flexibly uses elements from an honest counterpart in the individuals' repertoire) and long-term strategies (in which deception rests on fixed elements in the individuals' or species' behavioral repertoire).

From a *cognitive perspective*, tactical deception has been assumed to reflect *intentions* by the deceivers in the sense that individuals want to manipulate others. The critical question concerns the *degree of intentionality*, i.e., whether the deception aims to affect the other's behavior or the other's mental states. Deceptive interactions may thus be the result of a range of cognitive abilities such as reading behavioral cues, learning about and/or understanding behavioral maneuvers or even attribution of mental states.

In practice, it is difficult to distinguish between different orders of intentionality, as acts carried out to affect the beliefs of others do not look any different from acts that shall affect merely the others' behavior. To date, there is little evidence that nonhuman animals are capable of full mental state attribution (theory of mind), i.e., to understand that others have beliefs and desires, but there are some persuasive examples of precursor elements like visual perspective taking. Recently, attempts have been brought forward to specify *cognitive building blocks of deception*, which may underlie the transition from different orders of intentionality. The most promising among them are the ability to flexibly inhibit normal behaviors and the understanding that conspecifics can be manipulated.

Theoretical Background

In comparison to morphological and physiological traits, behavior is relatively easy and cheap to fake. Consequently, behavioral deception in the form of *withholding information* and *providing false information* can be found in variety of species and contexts ranging from predator–prey interactions to any form of intra- and interspecific communication, cooperation, and competition. To what extent these behaviors meet the functional definition and cognitive criterion of tactical deception and intentional deception, respectively, has received surprisingly little investigation.

To date, primates have been considered as primary candidates for intentional deception because their *complex social life* creates ample opportunities in which it would pay to flexibly conceal information, to distract others' attention, or to use others as social tools. Specifically, subordinate group members may use deceptive tactics to counter exploitation by dominants. However, *constraints* imposed by social structure, such as the risk of detection, punishment, and/or the need for cooperation, make deceptive tactics rare events that often work only for a short time period. Accordingly, deceptive tactics are difficult to study and much of the early literature on the topic consists of anecdotes. Nevertheless, progress in studying deceptive tactics and their cognitive basis has been made with experimental approaches that are based on ecological meaningful behaviors, such as outwitting conspecifics in competition for food. Moreover, species other than primates (from mammals to birds and fish), who also live in a complex social environment, have received increased attention.

Important Scientific Research and Open Questions

Experimental Studies on Intentional Deception

Studies concerning the cognitive underpinning of deceptive tactics may follow different experimental lines but generally make use of (experimentally induced or naturally occurring) variation in information about desired objects (i.e., food). The focus is either on how informed subjects act to prevent others from gaining these objects or on how naïve subjects respond to receiving false information.

In the "informed forager" paradigm, a particular individual gets informed about the location of food, usually by allowing her visual access to the hiding procedure. The subject is then allowed to retrieve the food together with other group members, which may be dominant and/or uninformed about the food location. In chimpanzees *Pan troglodytes*, mangabeys *Cercocebus torquatus*, and ravens *Corvus corax*, some subjects start withholding the correct information from naïve dominants (who are likely to steal the food) and learn to mislead them to false locations. In chimpanzees, dominant subjects may even develop counter tactics to avoid being cheated by subordinates. Other species, in contrast, seem to have problems in learning that others can be deceived (e.g., ring-tailed lemurs *Lemur catta*) or readily adopt alternative strategies to outwit others when misleading attempts are not successful (e.g., domestic pigs *Sus scrofa*).

Knower-guesser studies, originally designed for testing mental attribution, feature aspects of the informed foraging paradigm and frequently involve deceptive maneuvers on side of the informed subjects (knowers) against the uninformed guessers. Corvids like ravens and Western scrub jays *Aphelocoma californica* spontaneously hide from others when they cache food, and thus withhold information from possible competitors that could subsequently pilfer the caches. Ravens also actively distract others from cache sites and do false caches, indicating naturally occurring forms of misleading behavior. Likewise, chimpanzees and tufted capuchins *Cebus apella* may spontaneously conceal information and/or provide false information to naive conspecifics in food competition contests. Long-tailed macaques *Macaca fascicularis*, in contrast, do not seem to be capable of actively concealing information from a competitive human experimenter in the foraging context, although they frequently hide from dominant conspecifics during sexual intercourse.

For testing how animals respond to deception by others, studies usually involve the use of human experimenters, who either give false information in choice studies (i.e., they point out the incorrect location of hidden food) or they do not share the reward after having relied on the behavior of the test subject to find it. In most of these studies, nonhuman animals like apes, monkeys, and dogs *Canis familiaris* learn to provide no cues and/or to give wrong cues to the experimenter but only as a result of intensive training. Reversing the roles between experimenter and test subject leads to a drop in performance, which supports the interpretation that the animals base their deception on the others' behavior (which they have to learn anew) and not on an understanding of the others' intention.

Open Questions and Future Research

Complex social life involves various ways of communication, cooperation, and competition, offering a range of opportunities in which deception would pay off. Hence, tactical deception may be a widespread phenomenon that is primarily constrained by social structure (e.g., risk of detection, punishment) rather than by phylogeny. Empirical evidence for this assumption is still scarce but reports on mammals, birds, and recently also on fish point in this very direction. However, the occurrence of tactical deception does not allow inferring the underlying cognitive mechanism. Notably, tactical deception may reflect intentional behavior on side of the deceiver but does not need to reflect attribution of mental states. The critical points for future research are thus to study the acquisition and flexibility of deceptive tactics and to tease apart different levels of intentionality.

Cross-References

► Complex Learning
► Intelligent Communication in Animals
► Observational Learning: The Sound of Silence
► Social Cognitive Learning
► Social Construction of Learning

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Cognitive Aspects of Natural Communication in Primates

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Synonyms

Cognitive underpinnings of primate communication

Definition

Research on the "cognitive aspects of natural communication in primates" is on the psychological states, mental representations, and social awareness underlying primate communication. Communication involves the use of elements of an individual's behavioral repertoire to interact with others in a ritualized way by design or intention. Naturally produced communication signals are important because they are suited to reveal adaptive significance and evolutionary history.

Theoretical Background

Acts of communication require at least two participants, a signaler and a receiver, who interact with some ritualized code, such as a system of vocalizations, facial displays, or gestures (Seyfarth and Cheney 2003). In primates, communication is usually triggered by some external event which has a psychological effect on the signaler and elicits signal production. Receivers benefit from attending as long as the signal is a reliable indicator of the event experienced by the signaler or its response to it. For example, an eagle alarm call allows a monkey to run to cover before it has seen the approaching eagle. The production of signals is beneficial if it secures the survival of offspring, close genetic relatives, or valuable partners or if it reduces other costly consequences. Humans have by far the most complicated natural communication system of all primates, language, and its evolutionary origins are still much debated. Since language is a product of the human mind, research on primate communication is very concerned with the cognitive machinery underlying it.

Important Scientific Research and Open Questions

Key questions are the following: Is primate communication the product of mental representations that are shared by signalers and recipients? What is the nature of the different communication codes and how much flexibility do primates have when acquiring them? Are primates able to perceive graded signals categorically and do they combine them to more complex utterances? To what degree do they take context into account when producing and interpreting signals? Do they seek to inform others and check if they have been understood? Do primates assume that a signaler wants to be informative or is comprehension an eavesdropping process of learned correlations between signals and external events? From the different modes of communication (vocal, visual, olfactory), are there differences in the underlying cognitive processes that govern them?

Research with natural populations has been particularly useful in addressing some of these questions, recently also including great apes. It is now clear that nonhuman primates are able to produce messages that convey not only their inner states but also something about their external world, that they use various communication strategies to this end, and that they can develop a fairly complex understanding of the social consequences of their signals. Some profound differences between human and nonhuman communication have equally emerged, as summarized in the following.

Signal and Sequence-Based Meaning

A central problem in primate communication research concerns the psychological states underlying and driving signal production. A widely held belief is that nonhuman primates only experience different degrees of arousal, which act as the main agent of signal production. Another version of the arousal model is that different events trigger different *kinds* of arousal, which are then linked to signals. At the same time, there is good evidence that nonhuman primates possess mental representations and organize their world along mental concepts (Tomasello and Call 1997), and it seems unreasonable to assume that this should not also affect their communication. In the end, psychological states are private, but there are no empirical grounds to favor arousal-based vocal production over concept-based models. Whatever psychological states involved in signal production, primates often behave as if their signals convey meaning by referring to the external events or inner states that trigger the signals.

Most primates are forest dwellers, a habitat in which vocal communication is especially important. Nevertheless, primate vocal repertoires tend to be small, with a finite number of basic call types tightly linked to specific biological functions. However, sometimes individuals produce meaningful acoustic variants within some of the basic call types. For example, female Campbell's monkeys regularly exchange contact calls, which help individuals to stay with the group in the dense rainforest habitat. The calls are exchanged according to some social rules and are individually distinct. Some acoustic convergence effects have been reported in the structure of calls of closely affiliated group members (Zuberbühler et al. 2009). In other research, acoustic variation within call types has shown to convey details about external events. For example, chimpanzee screams during agonistic interactions reflect the nature of the event, the role of the caller, the severity of the attack, and whether high-ranking group members are nearby. Similarly, chimpanzees produce acoustically variable "rough grunts," which covary with the perceived quality of the encountered food (Zuberbühler et al. 2009). Yet a number of basic questions are still unsolved. What evolutionary processes can explain the acoustic structure of the different call types within a species' repertoire? Habitat structure, caller physiology, and receiver psychology are likely candidates, but the details are not well understood. How widespread are meaningful acoustic variants of basic call types in primate communication, and which call types are especially prone to acoustic variants? How much control do callers have during call production, and how do they acquire them? Why did humans evolve so much greater control over their vocalizations than all other primates?

A second mechanism by which nonhuman primates can increase their small repertoire is by combining different call types into sequences. This has been found in a number of primates, from Old World monkeys to gibbons and great apes. There is good evidence that receivers can discriminate the different sequences, i.e., they are semantically meaningful to them. Numerous questions remain open such as: Are meaningful call sequences a general feature of primate communication? Are there population differences in call sequences? How much control do primates have over call sequences, and what is the role of learning? A more difficult issue is whether sequential signaling is relevant for understanding the origins of human syntax. One notion of human syntax is that its basic units (e.g., words) have their own stable and independent meanings, something that has not been shown in the primate examples. Also, primates do not make much advantage of the generative power of call combinations, suggesting that they have very little active control or cognitive understanding of these vocal products.

One key issue in vocal production is the role of learning. A wealth of data has shown primate vocal repertoires are very species-specific with little acoustic variation between populations and rigid developmental patterns, suggesting that learning does not play an important role during ontogeny, at least at the level of call morphology. Of course, the same is also true for nonlinguistic human vocalizations, although humans are able to mimic calls fairly accurately and at will. Another key difference is that human infants go through a babbling phase and then gradually gain control over their vocal apparatus and learn to produce speech signals. In nonhuman primates, learning does play a role in developing call comprehension and call use. Individuals are generally very attentive to their own and other species' vocal signals, and appear to have a sophisticated understanding of the meaning of these calls. In terms of call use, young primates begin by generating the different call types in the appropriate larger context, but then learn how to fine-tune call production in more detail. The classic example is young vervet monkeys, who discriminate from the beginning between aerial and terrestrial dangers but require experience to produce the alarm calls to the few relevant predator classes. However, very little systematic research has been done, so it is not clear what the general pattern is like.

Research on gestural communication has generated a somewhat different picture, by showing that there is much variation in the gestural repertoire within different species, especially the apes. While some gestures appear to be almost universal, others can appear and disappear over time. Learning seems to play a role, with signalers and receivers converging on what looks like ontogenetically ritualized gestural conventions (Call and Tomasello 2007). In general, gestural signals are used much more flexibly than vocalizations, but they are also more restricted to some contexts, especially play. Many gestures do not carry much meaning apart from acting as enhancers of ongoing social interactions. One open problem in gestural research is also what exactly counts as a gesture, i.e., whether a behavior in question has proper signal character, either by design or intention. Other communicative modes, especially olfactory communication, are poorly researched and only little is known about the underlying cognition involved in production and perception.

Inferential and Intentional Processes

Another important cognitive process in communication is that primates take the ongoing context into account when responding to the signals of others. For example, terrestrial alarm calls often do not have narrow or fixed referents but are typically given to an array of events that do not always have an obvious shared conceptual structure. Context then plays a key role and primates often respond very differently to the same calls, depending on the circumstances, suggesting basic inferential reasoning. In one experiment, Diana monkeys responded differently to guinea fowl ground predator alarms, depending on whether the birds' alarm calls were caused by a leopard or a human, two predators that require different antipredator responses. Similarly, baboons attend to entire exchanges of calls between group members, a pattern also found in chimpanzees. In human communication, transmission of meaning also depends largely on the context in which the utterance is produced.

However, human communication goes beyond context contributing to the meaning of an utterance. Human speakers seek to establish common ground with their partners, by taking into account common knowledge, beliefs, and assumptions, while listeners also make assumptions about the speaker's intent. These skills develop gradually from early childhood and become first visible in joint attentional episodes during which both individuals are aware of each other's attention to an external object (Tomasello and Carpenter 2007). During subsequent stages of development, humans begin to monitor whether their communicative intentions are properly received and understood. There is currently no good evidence that nonhuman primates possess the same cognitive capacities to take shared knowledge and speaker intention into account during acts of communication. Yet, some key precursor abilities are in place, such as a general awareness of the audience and the likely consequences of producing signals. Audience awareness is particularly obvious in the gestural domain. Chimpanzees, for instance, will not produce visual gestures before having established visual contact with the receiver. Bonobos are capable of engaging in joint activities with human caregivers, in which both partners play complementary roles, and gesture to their (human) partners if they interrupt or are reluctant to pursue the joint activity. In the vocal domain, chimpanzees are aware of the composition of the audience and the potential implications of their calls, as shown by several studies (Zuberbühler et al. 2009). Whether or not apes are willing to actively inform others about relevant events in the world needs to be investigated more systematically, but it remains a possibility. Whether primates deal with ignorant receivers in different ways compared to knowledgeable ones is equally unclear, although they are able to make such discriminations in other contexts.

In sum, according to current evidence, nonhuman primates share many of the key features of human communication although humans appear to be unique in their ability to control their vocal tracts and in their motivation to base their communicative behavior based on shared knowledge and intentions. Primates may or may not have the required social cognition. If they do, they do not make regular use of it. Why only humans are socially motivated to inform each other about their experiences thus lies at the heart of the human–primate divide. One popular idea is that humans are more cooperatively motivated than other primate species, as for example reflected in high degrees of mutual tolerance or willingness to help strangers. Whether this cooperative propensity has evolved in the context of childcare, foraging, intergroup conflict, or elsewhere is unresolved.

Cross-References

- ► Comparative Psychology and Ethology
- ► Concept Learning
- ► Imitative Learning in Humans and Animals
- ► Intelligent Communication in Animals
- ► Social Cognition in Animals

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Cognitive Aspects of Prosocial Behavior in Nonhuman Primates

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Synonyms

Donation; Helpful Behavior

Definition

Prosocial behavior is any behavior performed by one individual that results in a benefit for another individual. *Prosocial motivations, prosocial preferences*, or *other-regarding preferences* refer to the psychological predisposition to behave in the best interest of another individual. A behavior need not be costly to the actor to be considered prosocial, thus the concept is distinct from *altruistic behavior* which requires that the actor incurs some cost when providing a benefit to another.

Theoretical Background

It is generally agreed that humans are a prosocial species; for example, we provide assistance to fellow humans by donating to charities, donating blood to strangers, and voting. A renewed interest in nonhuman primate prosocial behavior has emerged among comparative psychologists in the last decade. Currently, three hypotheses predominate the literature on prosocial behavior in nonhuman primates:

1. Prosocial behavior is uniquely human.
2. Prosocial behavior emerges from a cooperative breeding social system (a social system in which nonbreeding individuals help to care for infants).
3. Prosocial behavior is a general predisposition of nonhuman primates that reflects the early origins of human empathy.

Important Scientific Research and Open Questions

Recent investigations of prosocial behavior in nonhuman primates have often employed the *prosocial* *choice task*. In the prosocial choice task, subjects are presented with a choice between a prosocial option that provides a single reward (often food) to himself or herself and to the recipient (referred to as the "1/1" option to denote that one reward is received by the actor and one reward is received by the recipient) and another option which provides a reward for the actor only (the "1/0" option). The effort required of the actor is the same for both choices; the choices differ only by whether or not the recipient also receives a reward. The proportion of trials on which actors choose the prosocial option is compared with a control condition in which no recipient is present (a nonsocial control). Evidence of prosocial behavior is assumed if the actor chooses the prosocial option more often when a recipient is present to receive the reward than when there is no recipient present.

The resurgence of interest in nonhuman primate prosociality was sparked by findings indicating that chimpanzees did not demonstrate prosocial behavior on this task. In fact, chimpanzees across multiple captive populations chose randomly between the two choices, showing no increase in the prosocial response when a partner was present compared to absent (e.g., Silk et al. 2005). These findings provided initial support for the hypothesis that prosocial preferences are uniquely human and emerged in the human lineage after our ancestors diverged from the other great apes, or within the last six million years of evolution (hypothesis 1, above).

Positive results from additional primate species soon followed that suggested prosocial preferences are not uniquely human and may in fact be a characteristic shared by humans and cooperative breeding species (hypothesis 2, above). Across primate species, breeding systems can be arranged along a continuum defined by which individuals bear responsibility for offspring care. At one end of the continuum are independent breeders. In independently breeding species, care is provided nearly exclusively by the mother. This is the breeding system of most primate species, including chimpanzees. However, at the other end of the continuum are cooperative breeders in which many group members are actively involved in infant care, including the father, siblings, aunts, uncles and sometimes unrelated individuals. Helpful behaviors by the nonbreeding individuals are essential to the survival of the offspring. Some propose that ancestral hominids were cooperative breeders, that modern human minds are adapted for a cooperatively breeding environment, and that one of the ways the cooperative breeding environment influenced our psychology was to predispose individuals to behave prosocially (e.g., Burkart et al. 2009).

Therefore, the cooperative breeding hypothesis predicts that prosocial preferences would be expressed not by our closest living primate relatives the chimpanzees, but instead by cooperative breeders. In the primate order, cooperative breeding occurs in the taxonomic family Callithrichidae, the marmosets, and tamarins. Empirical support for the cooperative breeding hypothesis was generated by presenting marmosets and tamarins with the same prosocial choice task that was utilized with chimpanzees. Unlike chimpanzees, marmosets and tamarins demonstrated prosocial preferences (e.g., Burkart et al. 2009; Cronin et al. 2010). These findings support the hypothesis that there are psychological adaptations associated with cooperative breeding that positively influence prosocial preferences.

However, positive results from the prosocial choice task are emerging from primate species that are not cooperative breeders, indicating that cooperative breeding is not necessary for prosocial behavior (e.g., Massen et al. 2010). Furthermore, under some experimental conditions, cooperative breeders do not show prosocial preferences on the prosocial choice task (Cronin et al. 2009). These mixed results suggest that the expression of prosocial behavior will not be explained by social systems or evolutionary history alone and that prosocial behavior is dependent upon a myriad of ultimate and proximate influences. Along these lines, de Waal and colleagues have proposed that the proximate mechanism that elicits prosocial behavior among nonhuman primate species is empathy, or the sharing of an emotional state with another (hypothesis 3, above). de Waal argues that some basic form of empathy is present throughout the primate order. The likelihood of expressing prosocial behavior among primates therefore depends on the ability to match the emotional state of the potential recipient, an ability that will be affected by social factors such as the degree of social closeness with that individual (de Waal and Suchak 2010).

The proximate, psychological mechanisms that underlie prosocial behavior in nonhuman primates is a rich area for future research. For example, some results point to differences in the intrinsic reward experienced when providing benefits to another individual that may differentially reinforce prosocial behavior across species (e.g., Cronin et al. 2010). Other results suggest that the ability to inhibit one's own motivation for the reward is necessary for prosocial behavior to be expressed. Additionally, perspective-taking and theory of mind abilities may impact the execution of prosocial behaviors since realization of the needs of others may in some circumstances rely on these cognitive capacities. However, the influence of psychological mechanisms on prosocial behavior in nonhuman primates has received little attention. Research on the cognitive influences on prosocial behavior promises to provide some much-needed answers to the question of how and when prosocial behavior emerges among nonhuman primates.

Cross-References

► Intelligent Communication in Animals
► Social Cognition in Animals
► Social Learning in Animals

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Cognitive Automatisms and Routinized Learning

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Synonyms

Automatic encoding; Automatic process; Cognitive lock-in

Definition

The question of cognitive automatisms was first addressed from the perspective of individuals' attention and their limited capacities and bounded rationality. Shiffrin and Schneider (1977) consider two types of information processing. The controlled process is performed more slowly because it is maintained in working memory, which requires conscious effort and sustained attention. The automatic process, on the contrary, does not require attention in order to be performed.

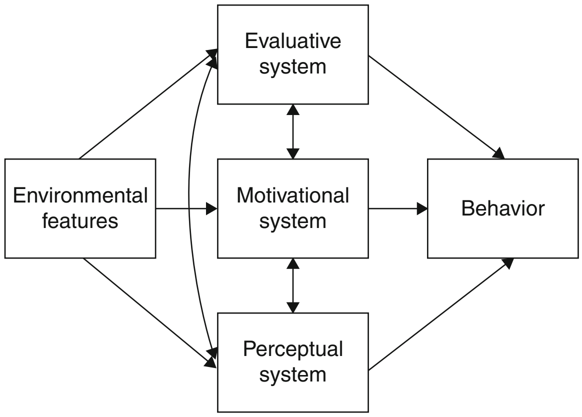
Theoretical Background

Shiffrin and Schneider's (1977) research has influenced research in cognitive science by suggesting that visual automation is different from motor-sensory automation. In the context of motor-skill development, automation is comparable to a flexible pattern subject to multiple parameters; it is not necessarily a rigid process as some might naively imagine. Shiffrin and Schneider (1977) distinguish several levels of automation: (a) a highly automatic type of information processing that does not require any particular attention; (b) a partly automatic process which attention can influence; and (c) automatic information processing that typically requires attention.

These studies concur with and complement the work of Anderson (1983) by putting in perspective the automatic process implemented by individuals. In the so-called proceduralization phase, knowledge is directly incorporated into procedures for the execution of skills, which makes it possible to minimize demands on working memory, but this can also lead to errors if the compilation phase is too short. In other words, the transition from declarative knowledge to procedural knowledge remains a delicate operation because the automatic process can lock some know-how into tight procedures that are not as subject to dynamic alternation as circumstances may actually require. Human judgment is, thus, necessary to update these procedures, but this may occur only after a mistaken application of an inflexibly automated procedure.

Bargh (1997) integrates principles of motivations as described in the self-determination theory. He observes to what extent the emotional, cognitive, and motivational conditions that characterize an environment can serve as the basis for a preconscious psychological state that can generate an automatic response – automatic in that it escapes the individual's awareness and direct consciousness. The underlying idea is that the routinization of certain procedures helps an individual focus his/her attention on essential, new, and creative tasks. What is new here is the manner in which Bargh analyses motivation. Indeed, nothing happens by accident. First of all, before walking may become an automatic process, we have learnt how to walk; and second of all we intend to walk. Bargh (1997) introduces an automotive model to explain to what extent mental representations are essential to the development of cognitive mechanisms (see Fig. 1).

The interactions between cognition and motivation are therefore essential and must be taken into account. Consciousness initiates the process of skill acquisition with possible tensions during this learning stage: "But even in the case of these automatic motivations, it is possible for a person to become aware of his or her actions and, as in the case of bad habits, attempt to change those behavior patterns. This question of how automatic and conscious motivations interact when in conflict is one of practical as well theoretical importance, and we are now investigating parameters of this interaction" (Bargh 1997, p. 52).



Cognitive Automatisms and Routinized Learning. Fig. 1 Motivation and behavior according to Bargh (1997)

Important Scientific Research and Open Questions

The question of consciousness in mental processes has always been a thorny one. Recent studies converge on the fact that the consciousness vs. automaticity opposition is a dichotomy that is not clear because it seems that consciousness and automation coexist and influence each other, sometimes in nonconscious ways. Psychologists agree that both processes evolve together. Acknowledging the role of consciousness in memorization implies recognizing that chance and the environment have a limited role. In terms of memorization, this boils down to no longer focusing all attention on the mechanisms of procedural knowledge learning, and to acknowledging the fact that declarative knowledge is essential. In other words the transition from representation to action is a mechanism that needs to be explained if we are to understand how our procedural knowledge evolves and why there is a gap between what an individual thinks he/she does and what he/she actually does. Modification of our forms of memorization must be considered in relation to changes. Individuals, as well as organizations, must learn to manage them, and to channel the emotions generated by modifications in the collective representations.

One may note that the debate on routines and automatisms has always had a more or less positive connotation because in everyday language, a routine is regarded as automatic behavior, in contrast to designed and implemented strategic plans. This is the reason why Langer (1989) emphasized the notion of mindfulness to highlight individuals' attention inside cognitive automatisms. In this perspective, individuals should make sense of what they do and perceive, by increasing their acuity so as to be able to integrate new information, to continuously update and refine their mental categories. Indeed, the notion of mindfulness emphasizes the necessity of focusing not so much on simple quantitative questions of data storing, but on the quality of the memorization.

Experimental studies show that working groups that apply this principle memorize what they learn better and are more creative (Langer 1989). This principle has also been implemented in complex technological environments so as to reduce the risk of accidents and prevent major technological disasters (Weick and Sutcliffe 2006). Potential change in routines should not be seen as a fateful coincidence related to external and disruptive factors, but as a crucial ingredient to the revitalization of individuals and organizations. This leads us to reconsider the very meaning of the term "routine" and to focus on individual and collective memorization processes. The involvement of individuals in the development of new procedural knowledge is a delicate exercise because deliberate reasoning and mindfulness attitude, at the individual level, is a controlled, effortful, process, whereas other cognitive activities such as reasoning or intuition appear to be effortless and to involve a level of automaticity. This also explains why learning may appear to be costly at an individual level and why the motivational dimension may play a critical role in going beyond preexisting cognitive skills that are deeply entrenched in the habitual skills. Indeed skill-based habits acquired through a trial and error learning process may become increasingly automated as a function of the amount experience with it, creating some "cognitive lock-in" resisting to changes. The organizational context may provide (or not) opportunities to go beyond these cognitive lock-in with the creation of systems that may facilitate learning.

Cross-References

- ▶ Automaticity in Memory
- ▶ Human Cognition and Learning
- ▶ Individual Learning
- ▶ Memory Dynamics
- ▶ Mental Effort
- ▶ Mindfulness and Meditation
- ▶ Motivation and Learning: Modern Theories
- ▶ Rote Memorization
- ▶ Routinization of Learning

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Cognitive Change

▶ Mediated Learning Experience (MLE) and Cognitive Modifiability

Cognitive Conflict and Learning

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Synonyms

Cognitive dissonance; Conceptual conflict; Disequilibrium; Socio-cognitive conflict

Definition

Cognitive conflict is a psychological state involving a discrepancy between cognitive structures and experience, or between various cognitive structures (i.e., mental representations that organize knowledge, beliefs, values, motives, and needs). This discrepancy occurs when simultaneously active, mutually incompatible representations compete for a single response. The detection of cognitive conflict is thought to trigger compensatory adjustments in executive control processes, which serve to reduce and prevent subsequent instances of similar cognitive conflict.

Theoretical Background

Cognitive conflict is a part of many different psychological theories, and has often been regarded as more deleterious than beneficial. For example, Freud (1901/1953) viewed distortions of rational thinking and neuroses as the result of conflict between basic drives. Similarly, early learning-theoretic investigations of conflict focused on different types of response competition that lead to negative outcomes (Miller 1944). However, other theorists such as Piaget (1977) and Festinger (1957) viewed the effects of cognitive conflict as playing a beneficial role in rational thinking and intellectual development, insofar as conflict drives positive cognitive adaptation.

Piaget viewed cognitive development as involving the attainment of successively higher states of equilibrium or balance. Piaget proposed that the mechanism of transition from one state of equilibrium to another was the process of equilibration. According to Piaget, this process is fueled by conflict or "disequilibrium," either between cognitive structures and experience or between various cognitive structures. Disequilibrium then motivates an individual to resolve the conflict and attain a new state of equilibrium.

One example used to illustrate the processes of equilibration is the acquisition of conservation of continuous quantity. A child is presented with two identical beakers that have been filled to exactly the same level with juice; one is identified as belonging to the child and the other to the experimenter. After the child has acknowledged that the amount of juice is the same in each beaker, the experimenter pours the contents of one jar into a short, broad container and that of the other into a tall, thin one. The experimenter then asks the child if the containers contain different amounts of liquid or the same amount. If the answer is the "same amount," the participant is said to have "conserved" the substance of the liquid; and with respect to this problem, the child's thinking has reached a new state of equilibrium.

According to Piaget, all equilibration processes go through four steps. In the Step 1, the child attends to only one dimension (e.g., the height of the container), and judges the tall drink to contain more liquid (i.e., fails to conserve quantity). With repeated experience on similar problems, in Step 2 the child then focuses on the opposite dimension (e.g., the width of the container), and judges the broad container to contain more liquid. The third step may be viewed as a mixture of the first two steps. More specifically, the child will now alternate responses between the two dimensions of the containers. This alternation provides the necessary conditions for the fourth step, which is simultaneous attention to both height and width and their coordination into a mutually compensating system. It is at this point that the child recognizes the two containers contain the same amount of liquid (i.e., conserve quantity).

Festinger's cognitive dissonance theory shares many similarities with Piaget's theory of equilibration. Festinger (1957) suggested that the perception of inconsistency between two simultaneously held ideas generates a state of psychological discomfort or cognitive dissonance. The theory of cognitive dissonance holds that individuals have a motivational drive to resolve dissonance by either changing their beliefs, attitudes and behaviors, or rationalizing their beliefs, attitudes, and behaviors. For example, it is widely accepted that smoking is associated with a greater probability of developing lung cancer. At the same time, most individuals desire to live a healthy life. On this account, the desire to live a healthy life is dissonant with engaging in activities that will most certainly shorten one's life. The conflict produced by simultaneously holding these contradictory ideas may be reduced by quitting smoking, or rationalizing one's smoking.

The ability to recognize and learn from instances of cognitive conflict is an important evolutionary adaptation, and as such, understanding the biological systems that underpin this ability remains an important line of research. Recent theoretical advances in cognitive neuroscience have started to shed light on the underlying neural mechanisms of cognitive conflict and its resolution. One theory that has garnered a considerable amount of attention is the conflict monitoring theory (for review see Botvinick et al. 2004). On this account, specific subsystems of the human brain detect instances of conflict in information processing, particularly response competition, and then engage other executive brain regions to diminishing conflict in succeeding time intervals. The anterior cingulate cortex (ACC) is thought to be the monitoring center that is responsible for the online detection of response conflict. The conflict signal that is detected by the ACC is then transmitted to other brain regions, such as the dorsolateral prefrontal cortex (DLPFC), to increase the level of cognitive control and reduce the amount of cognitive conflict.

Important Scientific Research and Open Questions

Many empirical investigations of the effects of cognitive conflict in human participants have shown that when conflict arises between behavioral responses in experimental tasks, performance is adversely affected in terms of speed and accuracy. For example, in the Stroop task, participants are presented with the name of a color printed in colored ink. The participant's task is to identify the color of the ink as quickly and accurately as possible. On high-conflict trials, when the color's name differs from the ink color, participants are slower and less accurate than on low-conflict trials, in which the color name and ink match one another, or than on neutral trials, in which the word is not color-related. A large corpus of neuroimaging studies in humans using event-related potential (ERP) recordings, and functional magnetic resonance imaging (fMRI) have reported activation of the ACC to be greater in high-conflict conditions relative to low-conflict or neutral conditions during the performance of different tasks designed to elicit conflict (cf. Botvinick et al. 2004; Mansouri et al. 2009).

Although the behavioral effects of conflict have been typically associated with decrements in speed and accuracy, this relationship is dynamically modulated by previous experience with conflict. More specifically, response latencies on high-conflict trials that are immediately preceded by high-conflict trials are shorter than those on high-conflict trials that are immediately preceded by low-conflict trials. Additionally, conflict-related ACC activation has been shown to be modulated by preceding conflict, with greater ACC activation observed on high-conflict trials that were preceded by low-conflict trials relative to high-conflict trials that were preceded by high-conflict trials. The facilitative effect of previous experience with conflict has been referred to as the "conflict adaptation effect"; and has been observed across a wide range of conflict tasks (cf. Botvinick et al. 2004; Mansouri et al. 2009).

Cognitive conflict appears to be a ubiquitous phenomenon that can also be observed in non-human primates and other animals. For example, studies using nonhuman primates tested on analogs of conflict tasks used in human research have shown similar behavioral responses to conflict as humans (cf. Mansouri et al. 2009). However, discrepancies between these two bodies of literature begin to emerge when the findings of single cell recording studies are taken into consideration. Recording studies in nonhuman primates have failed to find any evidence of conflict-related signals in the ACC (Mansouri et al. 2009). Reconciling these differences remains an important challenge for future research.

Many psychological theories, including developmental, social, clinical, and cognitive neuroscientific, have emphasized the importance of cognitive conflict. Despite the importance of cognitive conflict in many different psychological theories, the development of a unifying theoretical framework remains an important challenge for researchers.

Cross-References

- ► Cognitive Dissonance in the Learning Processes
- ► Metacognition and Learning

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Cognitive Curiosity

- ► Curiosity and Exploration
- ► Epistemic Curiosity

Cognitive Developmental Robotics

- ► Developmental Robotics

Cognitive Disequilibrium

► Cognitive Dissonance in the Learning Processes

Cognitive Dissonance

This term denotes a psychological phenomenon which refers to the discomfort felt at a discrepancy between what a person already knows or believes and new information or interpretation which contradicts prior knowledge or beliefs. Cognitive dissonance was first investigated by Leon Festinger and associates.

Cognitive dissonance is often combined with a feeling of frustration perceived when an agent holds two contradictory ideas at the same time; in order to eliminate this feeling, the agents may change his/her beliefs or rationalize bad choices – that is, one of the elements creating the discomfort.

Cross-References

► Cognitive Conflict and Learning

Cognitive Dissonance in the Learning Processes

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Synonyms

Cognitive disequilibrium; Knowledge gaps

Definition

In order to understand the relationship between cognitive dissonance and the process of learning, one must first examine how cognitive dissonance is defined from two perspectives. From the psychological perspective, cognitive dissonance is described as an uncomfortable internal state occurring when new information conflicts with commonly held beliefs (Festinger 1957). As an example, imagine being presented with evidence that the Earth revolves around the sun when your understanding is that the sun revolves around the Earth. From the educational psychology perspective, Piaget (1929) saw cognitive dissonance as a means to facilitate the cognitive processes of accommodation and assimilation, which are central to knowledge development. Accommodation and assimilation occur when learners are presented with new knowledge and must expend mental effort to integrate this information into their existing schema.

Both of these perspectives are informative when considering cognitive dissonance and the learning process. While the psychological perspective conceptualizes cognitive dissonance as something that must be resolved, those examining it from an educational perspective see it as an opportunity to foster schema construction and design opportunities for dissonance to promote the development of knowledge.

Theoretical Background

Learning processes involve the integration of new information into existing knowledge structures or schema. When new information is presented to learners that is unfamiliar or contradictory to their existing knowledge or schema, this triggers a phenomenon referred to as cognitive dissonance. Cognitive dissonance is a feeling of instability caused by inputs that contradict one's existing cognitive understanding (Festinger 1957). Empirical studies of the manifestation and effects of cognitive dissonance confirm that the need to resolve this dissonance is extremely motivating for humans and activates cognitive processes until the dissonance is resolved (Elliot and Devine 1994; Zanna and Cooper 1974).

Piaget (1975) defines the state of cognitive disequilibrium in much the same way but from an educational perspective. Piaget saw what he termed cognitive disequilibrium as an opportunity for cognitive growth. One of the assumptions of Piaget's Cognitive Development Theory states that when learners experience cognitive disequilibrium, their cognitive systems engage in a process of accommodation and assimilation as the new material is integrated into their existing schema. This dissonance is seen as an essential trigger for the learning process resulting in learners that are engaged in problem-solving activities and/or trial-and-error learning resulting in the construction of new knowledge structures. As an added benefit to the learning process, the motivational aspects of resolving cognitive dissonance create an environment where learners are continually exposed to content-relevant information facilitating deeper processing.

Applying Cognitive Dissonance to Learning Environments

As the process of knowledge acquisition involves integrating new knowledge with existing schema, allowing learners to be in a state of cognitive dissonance is ideal for new learning. Theories of cognitive dissonance can be applied to both problem-based learning and procedural learning.

Probably the most natural instructional environments in which to study the phenomenon of cognitive dissonance are ones that employ problem solving. In problem-solving exercises, learners are presented with information and are asked to use their knowledge to extract the correct information and solve the problem. As soon as learners are presented with the components of a problem (problem state, goals, operators), they begin the process of resolving conflicting information, selecting relevant information needed to solve the problem, and constructing a procedure to solve the problem. The intrinsic human need to move from disequilibrium to equilibrium creates a constant process of examining and reexamining information until a satisfactory solution is reached. This trial-and-error process leading to insight is a cornerstone for the design of game-based learning environments (Van Eck 2007). One key consideration in the design of these environments is to understand the relationship between the level of cognitive dissonance and the motivation to solve problems. Learners are quickly bored with a level of dissonance that is too easily resolved but on the other hand can be frustrated with a level of dissonance that is too high.

Cognitive dissonance can also be used to promote procedural learning. The impasse-driven learning theory (van Lehn 1988) is defined as a point in which learners are presented with a procedural step that cannot be accomplished due to a discrepancy in their knowledge base. This theory has been used to propose designs for expert systems in procedural domains such as mathematics. After reaching an impasse, learners go through a repair-and-reflect cycle replacing the discrepancy and completing the procedure. When using impasse-driven learning to design learning environments, the quality of the information used by the learners to continue with the procedure is of critical importance. Inaccurate information used to repair an impasse will result in internalized misconceptions of procedural knowledge. Historically, these misconceptions are difficult to repair and can result in persistent misunderstandings.

Important Scientific Research and Open Questions

The concepts surrounding cognitive dissonance are a foundational element in learning processes and can occur no matter what the knowledge level of a particular learner. An awareness that this phenomenon exists and the processes used by learners to resolve these discrepancies is critical to understanding learning processes. Designers interested in using the positive effects of cognitive dissonance should focus on the creation of situations where learners can satisfy their internal need to resolve dissonant information thereby increasing their deep processing of the content.

With the abundance of research in advanced learning technologies, adaptive systems, simulation, and game-based environments that require instructional approaches through problem solving, research in the effects of cognitive dissonance on learning processes is ongoing. Design-based research (Barab and Squire 2004) is a methodological approach that proposes the design of environments to specifically verify theories of learning and the effects of instructional design on the learning process. Because cognitive dissonance is closely related to problem solving, the design and evaluation of problem-based learning environments provides a perfect opportunity to test and validate assumptions about cognitive dissonance and the processes of learning.

Several specific questions can be addressed through design-based research to verify the effects of cognitive dissonance on learning and motivation to learn. For example, one might assess whether the level of cognitive dissonance has positive or negative motivational effects on learners. Variables such as level of challenge and affordances can be manipulated to increase or decrease levels of cognitive dissonance contributing to a deeper understanding of motivational issues such as learned helplessness where learners disengage from learning because they find the presentation and/or content too frustrating.

One of the important goals to be realized when designing instruction is to create environments where learners are encouraged to satisfy their internally driven need to fill in gaps in their existing schema. Designers of instruction can utilize theories like cognitive dissonance to manipulate affordances that will maximize positive intrinsic motivation and enhance the meaningfulness of learning environments.

Cross-References

► Complex Problem Solving
► Designing Learning Environments
► Development of Team Schemas
► Emotional Learning
► Emotions in Cognitive Conflicts
► Games-Based Learning
► Motivation and Learning
► Problem Solving
► Procedural Learning
► Schema Development
► Schema-Based Learning
► Schema-Based Problem Solving

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Cognitive Dissonances

► Discontinuities for Mental Models

Cognitive Efficiency

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Synonyms

Mental efficiency; Optimal thinking; Problem-solving efficiency

Definition

Cognitive efficiency (CE) is a multifaceted construct that describes the ability to reach learning, problem solving, or instructional goals through optimal use of mental resources. CE can be defined as optimal effort needed to perform a task, optimal performance on a task, or as the relationship between maximum performances on a task while exerting minimum effort (Hoffman and Schraw 2010).

In general, all views construe CE as the tradeoff between benefits such as increases in the rate, amount, or conceptual clarity of knowledge versus costs such as time, effort, or the cognitive resources expended to complete a task. Three main criteria influence the understanding and utility of CE: the discipline of application, measurement of the construct, and individual differences among learners.

Theoretical Background

Beginning in the late nineteenth century, experimental and behavioral psychologists such as Ebbinghaus, Hull, and Thorndike conducted research using tasks such as maze learning, the memorization of nonsense symbols, and learning word lists in an attempt to explain individual differences in efficient cognition. These researchers concluded that CE was based on the amount of time needed to complete learning, and significant within-person variability on tasks determined the relative efficiency of learning conditions. Concurrently, efficiency research in diverse disciplines including industry, economics, and management examined what methods and conditions fostered productive outcomes while minimizing waste. Combined, these findings have lead to a focus on CE research in three primary disciplines: philosophy, neurobiology, and education.

Philosophy

Spawned by the “efficiency movement” in the early 1900s, and popularized by Frederick Taylor’s work (1911) in scientific management, the philosophical view of CE combined psychological and sociological perspectives. This systemic approach stated that individual competence cannot be achieved without efficiency, and productive cultures are based upon the moral obligation of citizens to maximize effort and avoid wasting human resources. According to this view, maximal productivity influences all aspects of life, including application of efficiency principles to the science of education. Research grounded in the discipline of philosophy places strong emphasis on measuring teacher competence and attempts to quantify educational efficiency by determining optimal teaching methods.

Neuroscience

Neurologically, CE is assessed by the frequency, speed, and location of prefrontal cortical activity as measured by brain imaging technology such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET), which detects changes in cerebral blood flow or neural activation. Individuals with faster and more localized brain connectivity are deemed neurologically more efficient when fewer cognitive resources are used and less energy is expended to correctly solve cognitive processing tasks such as digit-symbol substitution or spatial reasoning tasks, for example, the Raven Progressive Matrices test. Slower processing and greater neurological activity is deemed less efficient and typically associated with lower intelligence and diminished performance (Neubauer and Fink 2009).

Individuals who complete tasks faster and with greater accuracy have lower brain activation and higher brain alpha levels, meaning they achieve superior task performance with less cognitive effort. However, many empirical ambiguities exist with the typical negative relations between brain activity and performance attenuated for complex tasks. Other variables including structured practice and adaptive strategy use mediate brain activation and increase neurological efficiency (Neubauer and Fink 2009). Additionally, the influence of gender is related to greater neural efficiency with female dominance on verbal tasks, and male superiority on spatial tasks.

Education/Psychology

CE research in education and psychology is focused in several diverse areas including problem-solving efficiency in mathematics, verbal efficiency in reading, and strategy efficiency across domains. Problem-solving efficiency is the ability to arrive at accurate problem solutions with minimal effort or time (Schraw and Hoffman 2010). Verbal efficiency emphasizes the ability to quickly decode text and enhance reading comprehension, while strategy efficiency focuses on how effectively learners apply strategies to solve problems quickly and accurately.

Much of the CE research in education and psychology has investigated the effectiveness of instructional design and pedagogy, or focused on determining what factors influence information processing during learning and problem solving. The characteristics of instructional materials such as the complexity of the information and the presentation modality affect CE. Grounded in cognitive load theory (Sweller et al. 1998) cognitive efficiency is constrained due to the limited capacity of working memory to process and store information simultaneously. Information that is intrinsically complex and presentation modalities that require learners to engage in extraneous processing (e.g., embedding descriptive labels for a diagram in text rather than near the diagram) reduce CE because they create excessive burdens on processing resources and can interfere with learning.

Measurement of CE

Three primary methods are used to measure CE, each with different computational formulas (Hoffman and Schraw 2010). Studies investigating *instructional efficiency* typically measure differences between performance and effort. These studies convert raw effort and performance scores obtained when completing tasks to standardized scores and measure the *difference* between control and experimental groups similar to calculating effect sizes. For example, according to this method of measurement, if two individuals have the same test score, the individual that spent less time or effort is deemed to be more cognitively efficient.

The second method is *processing efficiency*, which is a measure of the *ratio* of performance (i.e., accuracy or number of errors) divided by cost (i.e., time or effort) between participants in different groups (e.g., experimental and control groups). The primary focus is on rate of change, or change relative to the amount of effort or time that was needed to achieve accuracy. A student could either complete a task with greater accuracy, or with less time or effort, and be considered cognitively efficient. This method differs from the first method as the construct of interest is the *rate* of change, not the *difference* in change.

A third approach holds a factor constant (e.g., background knowledge) and uses existing CE measures to predict future outcomes of efficiency, similar to using a covariate for statistical control. For example, in a situation where an athlete is running an obstacle course, the athlete's efficiency using the ratio of time to distance may be the same or even worse than the previous run. Using previous information can be helpful to determine differences in CE over time by calculating the relative gain after additional instruction or practice. This method of measurement differs from those previously described as it calculates the *conditional rate of change* from an existing level of CE to measure relative gain, when some relevant prior measure of practice or learning is considered.

Important Scientific Research and Open Questions

Person variables, such as working memory resources and domain knowledge, influence CE. Learners have limited working memory resources, which means they can concurrently process and store limited amounts of information at any given time. Thus, the availability of working memory resources influences how much information learners can process, how quickly they can process it, and the strategies they use to process it (Hambrick and Engle 2003). For instance, individuals with greater working memory capacity (WMC) typically solve problems more accurately and more efficiently than individuals with lesser WMC (Mayer and Wittrock 2006).

Domain knowledge influences CE. When individuals have knowledge that is deep, well-structured, and schematically well-organized, they think more efficiently, use strategies judiciously, and are better able to retrieve information from long-term memory. Other person variables that influence CE include metacognitive awareness and motivation. Metacognitive awareness involves knowing what strategies to use, and how and when to use them. Furthermore, learners' motivation to use strategies influences CE. So domain knowledge, metacognitive awareness, and motivation can help students become more cognitively efficient, even if they have lower WMC.

Instructional variables, including the quality of instructional materials and the presentation format of to-be-learned information, also influence CE. Materials enhance CE when individuals can expend less effort and achieve relatively higher performance outcomes. For example, when solving problems using worked examples, a modeled sample problem, learners are more successful than when merely asked to solve a problem without aids. Overly complex or poorly designed materials lower CE because learners waste valuable working memory resources deciphering materials and thus devote less attention to learning.

CE can be inhibited even when learners possess necessary domain knowledge and WMC. Individuals lacking in awareness or the motivation to use automated strategies may forego efficient problem solving in favor of more time-consuming methods such as calculation. Similarly, effort can influence the potency of cognitive resources dedicated toward a task, with greater effort associated with more complex tasks and a reduction in CE. The extra effort strains WMC resulting in longer problem-solving time, thus reducing efficiency. Although employing more effort usually impedes CE, overconfidence in problem-solving success can result in withholding effort. Individuals anticipating success may not try as hard as usual, miserly appropriating effort, resulting in lower performance, and ultimately reducing CE.

The mode of presentation, context of learning, and the nature of pedagogy may influence CE. Some materials are more suitable to the schemata of experts than novices and instructional methods such as discovery learning can be counterproductive (Kirschner et al. 2006). These facets of CE assume knowledge acquisition and problem-solving ability of a more seasoned learner can be encumbered by information which is redundant or unnecessary. Materials or methods providing information ancillary to learning can create cognitive congestion, lowering CE.

C

Enhancing CE

CE may be enhanced by using three related approaches: attentional control, optimal allocation of working memory resources, and adaptive strategy use. Attentional control, the ability to inhibit activation of irrelevant or distracting information (Hambrick and Engle 2003), involves focusing on information that enables a learned to reach a goal, such as solving a problem or comprehending a text. By directing attention toward relevant information, such as identifying key numeric values in a math story problem, individuals can direct working memory resources toward knowledge acquisition. CE relies on speed of processing, thus individuals that can automate knowledge using little conscious activity have a decisive advantage in both problem solving and recall (Mayer and Wittrock 2006). When information processing is automated, processing speed is increased, effort is reduced, working memory resources are conserved, and attention can be devoted to higher-order thought processes.

How individuals represent, allocate, and store knowledge in their long-term memory can also improve CE. The concise organization and allocation of knowledge structures such as well-defined schemas for declarative knowledge and automated scripts for procedural knowledge contribute to less effortful processing (Schraw 2006). Individuals with more awareness of their cognitive processes can achieve better knowledge organization thus freeing up available resources to more effectively process information. Finally, individuals may compensate for limited working memory resources through adaptive strategy use, motivational superiority due to higher degrees of self-efficacy, and through the use of instructional scaffolds such as worked examples or explanatory feedback, which enhance the overall efficiency of strategy use and subsequent CE.

Additional research in CE is needed in two areas. First, it is unclear as to which individual difference variables influence CE. More research is needed to determine how individual differences in motivation, reasoning, thinking dispositions, and beliefs influence CE. Individuals may be efficient at storing and processing information yet may apply their knowledge inefficiently.

Second, measurement approaches are inconsistent across and within disciplines. For example, some researchers measure cognitive efficiency strictly based upon the difference between performance and effort, while others use a variety of cost factors such as time or effort to create a performance ratio. Inconsistent approaches may deem a learner efficient under one circumstance but less efficient under another.

Cross-References

► Cognitive Load Measurement
► Cognitive Models of Learning
► Cognitive Skill Acquisition
► Cognitive Tasks and Learning
► Human Cognitive Architecture
► Measurement of Learning Processes and Outcomes
► Mental Effort
► Working Memory

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Cognitive Instruction

This conception can be defined as efforts for helping students to process information meaningfully, enabling them to becoming independent from the teacher. Cognitive instruction also reflects ideas of social constructionism as described by Lev Vygotsky (1978) in his work "Mind in Society": learners construct knowledge in a social context as they try to make sense of it, continually modifying prior knowledge as they apply it to new contexts."

Cognitive Jump

► Mental Leap

Cognitive Learning

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Synonyms

Knowledge change; Learning

Definition

Cognitive learning is a change in knowledge attributable to experience (Mayer 2011). This definition has three components: (1) learning involves a change, (2) the change is in the learner's knowledge, and (3) the cause of the change is the learner's experience. An example of cognitive learning includes being able to give the definition of cognitive learning after reading this entry.

Cognitive learning can be distinguished from behavioral learning on the basis that cognitive learning involves a change in the learner's knowledge whereas behavioral learning involves a change in the learner's behavior. However, a change in knowledge (i.e., cognitive change) must be inferred from the learner's behavior (i.e., behavioral change), so cognitive learning is closely related to behavioral learning.

Knowledge change is at the heart of cognitive learning; so it is useful to distinguish among five kinds of knowledge (Mayer 2011):

Facts – factual knowledge about the characteristics of things, such as knowing that the numeral "5" corresponds to the word "five"

Concepts – models, schemas, categories, or principles, such as knowing the difference between a circle and a square

Procedures – step-by-step processes, such as knowing how to carry out long multiplication for $56 \times 27 =$ ___

Strategies – general methods for accomplishing a goal, such as breaking a problem into parts or managing the learning process

Beliefs – thoughts about how one's learning works, such as thinking "I am good at learning about psychology"

Achieving proficiency on most complex tasks requires learning more than one kind of knowledge, including *meta-strategies* for how to coordinate them (i.e., strategies for managing cognitive processing).

Theoretical Background

The *science of learning* is the scientific study of how people learn (Mayer 2011). Over the past 120 years, researchers have developed three conceptions of how learning works – *response strengthening, information acquisition*, and *knowledge construction*. According to the response-strengthening view, learning involves the strengthening or weakening of an association between a stimulus and a response, in which responses that are followed by satisfaction are strengthened and responses that are followed by dissatisfaction are weakened. The instructor is a dispenser of rewards and punishments whereas the learner is a passive recipient of rewards and punishments. The response-strengthening view reached prominence in the first half of the twentieth century, and is reflected in classic research by Thorndike (1911/1965) on trial and error learning by cats.

According to the information acquisition view, learning involves adding new information to memory, in which the amount of practice or time spent studying is related to the amount of information learned. The instructor is a dispenser of information and the learner is a passive recipient of information. The information acquisition view reached prominence in the 1960s and 1970s in conjunction with the information-processing revolution in cognitive psychology, and has its roots in classic research by Hermann Ebbinghaus (1885/1964) on the role of practice in memorizing lists of nonsense syllables.

According to the knowledge construction view, learning is an active process of sense making in which the learner constructs a mental representation by selecting relevant incoming information, mentally organizing it into a coherent structure, and integrating it with appropriate prior knowledge. The instructor is a cognitive guide who helps the learner engage in appropriate cognitive processing during learning, and the learner is an active sense maker. The knowledge construction view has been prominent since the 1980s, and has its roots in classic research by Frederic Bartlett (1932) on learning and memory as constructive activities that depend on the learner's existing knowledge.

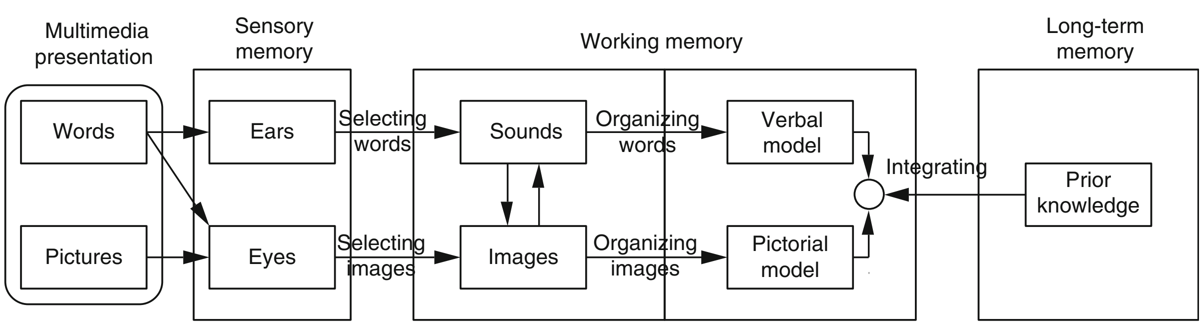
Although all three conceptions of learning are still influential today, they may be most relevant for different kinds of learning situations.

Important Scientific Research and Open Questions

Figure 1 presents a framework for cognitive learning, which consists of two channels, three memory stores, and three cognitive processes (Mayer 2009). Concerning channels, the top row represents the auditory/verbal channel whereas the bottom row represents the visual/pictorial channel. This distinction is consistent with the *dual-channel principle*, which holds that learners have separate channels for processing verbal and visual material.

Concerning memory stores, the first row represents sensory memory in which incoming spoken words impinge on the ears and are held in acoustic form for a very brief time within auditory sensory memory whereas incoming pictures and printed words impinge on the eyes and are held in visual form for a very brief time within visual sensory memory. These sensory memories have unlimited capacity to hold sensory representations for very brief periods (i.e., less than 1 s). The second row represents working memory in which selected aspects of incoming sounds and images from sensory memory are mentally organized into coherent cognitive verbal and pictorial representations, respectively. However, working memory capacity is severely limited; so only a small amount of cognitive processing can take place within each channel at any one time, and information that is not processed decays quickly (i.e., in less than 1 min). Finally, the third row represents long-term memory, which is the learner's storehouse of knowledge – a memory store for knowledge with nearly unlimited capacity and long duration. These distinctions are consistent with the *limited-capacity principle*, which holds that learners can process only a small amount material at any one time in working memory.

Concerning cognitive processes, the arrows represent the three major kinds of cognitive processing required for cognitive learning – *selecting, organizing*, and *integrating*. Selecting occurs when learners attend to aspects of the incoming information in sensory memory for further processing in working memory, as indicated by the arrows from sensory memory to working memory (i.e., *selecting words* and *selecting images*). Organizing occurs when learners mentally arrange verbal elements into a coherent verbal representation (indicated by the *organizing words* arrow) and mentally arrange pictorial elements into a coherent pictorial representation (indicated by the *organizing images* arrow). Integrating occurs when learners activate relevant knowledge from long-term memory and connect it with incoming information in working memory (as indicated by the *integrating* arrow).



Cognitive Learning. Fig. 1 A framework for cognitive learning

These cognitive processes are consistent with the *active-processing principle*, which holds that meaningful learning depends on appropriate cognitive processing during learning such as selecting relevant incoming information, organizing it into a coherent mental representation, and integrating it with appropriate prior knowledge.

Important research questions concern the nature of learning processes, the nature of mental representations, and the design of effective instruction. First, research is needed to determine how the processes of selecting, organizing, and integrating work during learning. Second, research is needed to determine how various kinds of knowledge are represented in working memory. Third, research is needed to determine how to guide learning by using effective instructional design.

Cross-References

- ▶ Cognitive Load Theory
- ▶ Cognitive Processes in Learning
- ▶ Constructivist Learning
- ▶ Ebbinghaus, Hermann
- ▶ Generative Learning
- ▶ Human Information Processing
- ▶ Knowledge Representation
- ▶ Multimedia Learning
- ▶ Thorndike, Edward L

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Cognitive Learning Strategies

▶ Elaboration Strategies and Human Resources Development

Cognitive Learning Strategies for Digital Media

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Synonyms

Approaches to learning; Learning methods

Definition

According to Streblow and Schiefele (2006), a learning strategy is defined as "… (a) a sequence of efficient learning techniques, which (b) are used in a goal-oriented and flexible way, (c) are increasingly automatically processed, but (d) remain consciously applied" (p. 353, translation by the author). Learning techniques denote both specific internal learning activities, such as remembering a piece of information or establishing a relation between pieces of information, and external learning activities, such as highlighting and annotating information in external representations. When several learning techniques are employed together in a coordinated and goal-oriented way, they form a learning strategy. Cognitive learning strategies serve to effectively and efficiently process information, to store information in long-term memory, and to support the retrieval of information.

Theoretical Background

In digital learning environments, learning material is frequently comprised of different static and dynamic verbal and pictorial representations. Educators combine both verbal representations (e.g., written or spoken text) and pictorial representations (e.g., pictures, animations, or simulations) in order to improve students' learning. This can have various beneficial effects on learning. For instance, different representations might single out different aspects of a subject domain, describe aspects of a subject domain that cannot be described by means of other representations, or complement each other in such a way that more complete mental representations are achieved (cf. Ainsworth 2006).

During the last 10 years, however, educational and psychological researches have demonstrated that many students encounter difficulties when learning from combinations of different verbal and pictorial representations. Such combinations not only offer various learning opportunities for students, but also place increased demands on the students. For instance, students need to understand (1) how information is encoded in each single representation, (2) how each representation is related to the subject domain, and (3) how information in one representation can be related to information in another representation (cf. Ainsworth 2006). Thus, students not only have to learn how to identify the relevant components of verbal and pictorial representations, but how to relate them to each other as well. If the representations are dynamic, students must also learn how to identify and relate both spatially and temporally separated components. Interactive representations place even more demands on the students in that they need to plan, to monitor, and to evaluate their interactions with the representations.

One approach to support learning from different static and dynamic representations is the principled design of digital media. Based on theories and models of human learning, such as Richard Mayer's (2001) theory of multimedia learning, this approach essentially aims at designing digital media in a way that make the identification and selection, as well as the organization and integration of information as easy as possible for students. Examples of important design principles are the multimedia principle, the split-attention principle, and the modality principle (cf. Mayer 2005). Several studies have demonstrated that the principled design of digital media facilitates learning. Over the past 10 years, research on learning from digital media has focused on this approach.

Another approach to improve learning from external representations is the principled design of learning strategies. Also based on theories and models of human learning, it aims at empowering students to initiate, plan, organize, monitor, and regulate their own learning and to competently deal with challenging learning material. With respect to learning from digital media, this approach has been largely neglected up until now.

One example in which research on the design of external representations has been successfully coupled with research on the design of cognitive learning strategies is when applied to learning from texts (e.g., Thomas and Robinson 1972). Numerous principles have been identified on how to design texts in a manner, which support students' learning. These principles address issues of content as well as structure and layout. No one assumes, however, that texts designed according to these principles guarantee that students will learn successfully. Rather, students are taught – from the elementary to the university level – reading and learning strategies which take the specific characteristics of texts into account. These strategies involve both internal learning activities (e.g., paraphrasing text segments) and external learning activities (e.g., highlighting text segments). Thus, after many years of education, the students have acquired and exercised a number of internal and external techniques which help them to systematically approach particularly complex and difficult texts.

If empirically evaluated strategies for learning from texts are available, but there exist almost no strategies for learning from other external representations, then one obvious approach to conceptualizing strategies for learning from other representations is to draw upon the strategies for learning from texts. However, strategies for learning from texts cannot be directly mapped onto strategies for learning from other representations. Because each external representation has its own characteristics and places its own demands on learners, a conceptual model that mediates such a mapping is needed. Theories on multimedia learning create a promising starting point for formulating the required conceptual model.

Mayer's (2001) theory of multimedia learning emphasizes four different kinds of cognitive processes: selection, organization, transformation, and integration of information. Selected textual and pictorial information is initially processed in separate channels. Subsequently, the selected information is then organized into two separate models: one model for verbal information and one model for pictorial information. During information processing, verbal representations may be transformed into pictorial representations (e.g., by constructing mental images) and vice versa (e.g., by internally verbalizing images). In order to make multimedia learning successful, both models need to be integrated and related to prior knowledge.

If strategies for learning from multimedia are to be based on strategies for learning from text, the models can support this conceptualization in two different ways. First, learning techniques used in strategies for learning from text can be categorized according to the cognitive processes which they aim to induce. Subsequently, analogous techniques for learning from multimedia have to be constructed in such a way that they stimulate the same cognitive processes. In this case, the model serves as a synthetic aid for "mapping" techniques, which have been designed for learning from one representational system to those techniques designed for learning from another representational system. Secondly, once a learning strategy is available, the learning techniques employed within the strategy can be categorized, as described above, in order to determine whether each of the cognitive processes is promoted by a corresponding learning technique. In this case, the model serves as an analytic aid in order to verify that all four kinds of cognitive processes are supported by the strategy.

Important Scientific Research and Open Questions

Based on the conceptual model described above, Kombartzky et al. (2010) proposed a cognitive strategy for learning from animations and spoken text. Two different experimental studies were conducted in order to evaluate the strategy. In the first study, one group of students learned from an animation without the strategy, whereas a second group of students was encouraged to make use of the proposed strategy during learning. The use of the strategy was not monitored. The students who were encouraged to take advantage of the strategy learned significantly better than the students who were not asked to do so. In the second study, three groups of students were investigated. The first group learned from an animation without the strategy. The second group was encouraged to make use of the strategy during learning but use of the strategy was not monitored. The third group was also encouraged to make use of the strategy during learning and their use of the strategy was monitored. The results of the second study replicated the findings of the first study. Furthermore, learning was most successful when the students' use of the learning strategy was monitored. The effect sizes are medium to large.

On the basis of the same conceptual model, Schlag and Ploetzner (in press) developed a cognitive learning strategy in order to support learning from written text and static pictures. Two groups of students were investigated in order to analyze the learning effectiveness of the strategy. One group of students learned without the strategy whereas another group of students learned with the strategy. It was demonstrated that the students who employed the strategy attained significantly better learning results with medium to large effect sizes.

The strategies proposed by Kombartzky et al. (2010) and Schlag and Ploetzner (in press) are two examples of cognitive strategies for learning from different combinations of digital media. Additional examples of such strategies are self-explaining while learning from text and pictures (e.g., Ainsworth and Loizou 2003) and guided discovery learning while learning from interactive simulations (e.g., de Jong and van Joolingen 1998). However, there is much potential for further research on strategies for learning from digital media. For instance, a learning strategy can be provided to the students in many different ways. The complete strategy can either be presented to the students at once on a worksheet or the students can be prompted incrementally and adaptively for single learning techniques when they are working on specific parts of the learning material. Currently, we do not know which possibility is more beneficial to learning.

In the long run, one also needs to investigate whether the learning strategies can be taught to students in such a way that the students internalize the strategies step by step and then automatically apply them to new learning situations. This commonly requires the training of learning strategies over a longer period of time. Research indicates that the use of a newly acquired, but not yet automatized learning strategy demands a great deal of mental effort and might therefore – temporarily – even impede learning. Only after a longer period of training does it become easier to apply the strategies, hence learning improves.

There might also be potential for optimizing the proposed strategies. On the one hand, we need to better understand how the learning techniques employed in the strategies contribute to learning success. Are the learning techniques of equal importance or could some of the learning techniques be neglected? On the other hand, only processes at the cognitive level are currently induced by means of the strategies. Various studies, however, indicate that learning might be even more successful if processes at the metacognitive level were also taken into account. It could therefore be of interest to further investigate whether or not it is beneficial to complement the proposed learning techniques at the cognitive level with learning techniques at the metacognitive level.

Cross-References

- ► Animation and Learning
- ► Audio-Visual Learning
- ► Cognitive and Affective Learning Strategies
- ► Learning Strategies
- ► Multimedia Learning
- ► Representational Learning
- ► Strategic Learning

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Cognitive Learning Strategy

Goal-directed mental activities aimed at enhancing one's knowledge and skill. Examples of cognitive learning strategies include summarizing, outlining, concept mapping, creating analogies, generating elaborations, sub-goaling, self-questioning, etc.

Cognitive Load

► Mental Effort

Cognitive Load Measurement

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Synonyms

Measurement of working memory load; Workload measurement

Definition

Cognitive load can be defined as the load imposed on an individual's working memory by a particular (learning) task. It can be measured using various techniques.

Theoretical Background

Cognitive load theory (CLT) is discussed extensively elsewhere in this Encyclopedia, and therefore not repeated in detail here. What is important to note for cognitive load measurement, though, is that the intrinsic load imposed by a learning task results from both task and learner characteristics. The higher the number of novel interacting information elements a task contains, the higher the intrinsic cognitive load it imposes on working memory. With increasing practice, elements are combined or chunked into a schema, which is stored in long-term memory and can be retrieved and handled in working memory as a single information element. Because schemata can be handled as a single element, the same task imposes less cognitive load for people who have had more practice than for people who are unfamiliar with the task, that is, their performance is more efficient. Therefore, measuring cognitive load next to the more traditional performance measures (e.g., accuracy, number, or type of errors), before, during, or after a learning phase, can provide additional information on the level of expertise of a learner or group of learners relative to that of other learners.

Next to intrinsic cognitive load, the way in which the task was designed or presented to the learner may affect cognitive load. In this case, measuring cognitive load in combination with performance can – at least when the level of intrinsic load is kept constant – provide information on the effects of different task designs relative to each other. For example, when we know that two groups of learners (A and B), of equal levels of expertise (i.e., materials will impose a comparable intrinsic load), both experience the same level of cognitive load during learning with two different instructional formats, say A (Group A) and B (Group B), we do not know very much. However, if we know that the learning outcomes of Group B were higher than those of Group A, we can conclude that the cognitive load they experienced must have resulted from different cognitive processes: The load experienced by Group B was imposed by cognitive processes that were more effective for learning than those in Group A. Or alternatively, if Groups A and B had obtained the same test scores, but Group A experienced more cognitive load during learning than Group B, the learning process of Group B was more efficient (Van Gog and Paas 2008).

In sum, cognitive load is the load imposed on working memory by the cognitive processes that a (learning) task evokes. It can be measured at different levels. Xie and Salvendy (2000) distinguish between instantaneous load, peak load, average load, accumulated load, and overall load. Instantaneous load reflects the dynamics of cognitive load, which fluctuates every moment during execution of the (learning) task. Peak load is the maximum value of instantaneous load while working on the task. Accumulated load is the total amount of load that the learner experiences during a task. Average load represents the mean intensity of load during the performance of a task. The average value of instantaneous load equals the accumulated load per time unit. Finally, overall load is the experienced load based on the whole working procedure (see also Paas et al. 2003).

Important Scientific Research and Open Questions

Cognitive load can be measured with different techniques. Most CLT research applies subjective rating scales to assess cognitive load, such as an adapted version of the NASA-Task Load Index (NASA-TLX) or (an adapted version of) the 9-point symmetrical category mental effort rating scale developed by Paas (for reviews, see Paas et al. 2003; Van Gog and Paas 2008). This mental effort rating scale asks students to indicate "how much mental effort did you invest in solving this problem?" (or "...in studying this example," or "...in completing this task"), with answer options ranging from (1) very very low mental effort to (9) very very high mental effort. Mental effort is defined as "the aspect of cognitive load that refers to the cognitive capacity that is actually allocated to accommodate the demands imposed by the task; thus, it can be considered to reflect the actual cognitive load" (Paas et al. 2003, p. 64). To illustrate the difference between "objective" cognitive load (e.g., as defined by the number of interacting information elements) and actual cognitive load as measured by mental effort: if a task is very high in intrinsic load, but the learner does not allocate any cognitive capacity to the task (i.e., does not engage in it, which can be the case, e.g., when learners perceive a task as being *too* difficult), the task will not actually impose any cognitive load on the learner's working memory. Subjective ratings are usually collected immediately after each task, in which case they do not give insight into fluctuations in load over time. They can also be applied repeatedly during the task, in which case, some information on fluctuations in load is available.

A more objective way of measuring cognitive load is the use of secondary-task procedures, in which the amount of load imposed by the primary (learning) task is measured by the performance or response time on a secondary task: the higher the load imposed by the primary task, the less cognitive capacity is available for attending to the secondary task, and as a consequence, response to the secondary task will be hampered/slower (for a review, see Brünken et al. 2003). For example, learners could be asked to respond to a color change of a letter placed above the multimedia materials they are studying as soon as possible (see Brünken et al. 2003). The slower their response to the color change, the more cognitive capacity was being devoted at that moment to the multimedia materials. Note that in order for the secondary task to be sensitive to variations in cognitive load, it should draw on the same working memory resources as the primary task. Moreover, if learners decide to devote more cognitive capacity to the secondary task, this might hamper their performance on the primary (learning) task (Brünken et al. 2003).

Both secondary-task procedures and subjective rating scales that are applied multiple times during task performance do not provide a *continuous* measure of fluctuations in cognitive load, because of the time intervals between presentations of the rating scale or secondary task. Continuous measurement of (instantaneous) cognitive load allows looking at data for specific instances of time, which will allow a more detailed interpretation of the effects of instructional interventions on cognitive processes, cognitive load, and learning than a single measure of accumulated or overall load. Objective cognitive load measurement techniques that have been explored in CLT research which can provide continuous measures, thereby allowing for assessment of cognitive load at all levels (instantaneous, peak, accumulated, average, and overall), are psychophysiological measures such as heart-rate variability, with increases in cognitive load being associated with decreases in variability, or pupil dilation, with increases in cognitive load being associated with increases in dilation (see Paas et al. 2003). Increasingly, psychophysiological techniques from neuroscience are being applied to study cognitive load, such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET), or electroencephalography (EEG). Both PET and fMRI are neuroimaging techniques that register changes in blood flow related to neural activity, using scanners; EEG measures electrical activity produced by the brain via electrodes that are placed on the scalp. Interestingly, research using a combination of behavioral and neuroscience techniques has shown that the cognitive efficiency discussed above (i.e., individuals with more expertise perform better while they experience lower cognitive load, i.e., have to invest less mental effort) also occurs at a neural level: Better performance is reached with a lower level of neural activity (Grabner et al. 2006; see also Antonenko et al. 2010). Traditionally, a major drawback of most psychophysiological measurement methods has been that the equipment is highly intrusive and difficult to use in natural settings. However, more options are becoming available and affordable for psychophysiological data collection in natural settings, such as head-mounted eye trackers connected with a laptop computer in a backpack, or wireless EEG caps.

Cross-References

- ► Cognitive Efficiency
- ► Cognitive Load Theory
- ► Mental Effort
- ► Working Memory

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Cognitive Load Theory

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Definition

Cognitive load theory is concerned with the manner in which instruction should be presented and the activities in which learners should engage to maximize performance. The theory is based on our knowledge of human cognitive architecture, particularly working memory and long-term memory. Relations between working memory and long-term memory are considered from an evolutionary perspective.

Theoretical Background

Cognitive load theory has a particular view of human cognitive architecture (Sweller 2003; Sweller et al. 2011; Sweller and Sweller 2006), and the type of knowledge that is acquired during instruction. The theory applies solely to biologically secondary rather than biologically primary knowledge (Geary 2008). We have evolved to acquire primary knowledge such as listening to and speaking our first language, recognizing faces, engaging in routine social relations, and using general problem-solving strategies, over many generations. Each of these skills is modular and not closely related to other primary skills. Primary knowledge can be acquired effortlessly, unconsciously, and without explicit instruction by immersion in a human society.

Secondary knowledge is cultural. We have not required specific examples of secondary knowledge until relatively recently and so have not evolved to acquire any particular form of such knowledge. For example, we have not specifically evolved to read and write in the way we have evolved to listen and speak. Similarly, it is plausible to argue that we have not evolved to acquire the content of any subject commonly taught in educational institutions. In contrast to primary knowledge, the acquisition of secondary knowledge requires a general cognitive architecture applicable to a wide variety of areas, rather than modular systems specific to a particular area. Furthermore, acquiring secondary knowledge tends to be effortful, conscious, and enhanced by explicit instruction. The cognitive architecture used by cognitive load theory applies to secondary rather than primary knowledge and is central to cognitive load theory. When dealing with secondary knowledge, human cognition can be considered a natural information processing system whose evolution has been driven by an analogous natural information processing system, evolution by natural selection (Sweller and Sweller 2006). The characteristics of natural information processing systems as applied to human cognition will be described using five basic principles.

The *information store* principle deals with the storage of information in human long-term memory. All learning requires information to be stored in long-term memory. If nothing is stored in long-term memory, nothing has been learned. In biologically secondary areas, massive amounts of domain-specific information in schematic form are stored in long-term memory. The primary goal of instruction is to assist learners to store that information.

Because the amount of information stored in long-term memory is so large, an efficient procedure for acquiring that information is required. That procedure is provided by the *borrowing and reorganizing* principle. Information is borrowed (and reorganized) from the long-term memories of other people by imitating what they do, listening to what they say, and reading what they write.

While information can be borrowed from other people, that information must be created in the first instance. Information is created during problem-solving by the *randomness as genesis* principle, using a random generate and test for effectiveness procedure. Random generation of moves can result in an unmanageable number of possible moves. Knowledge held in long-term memory is used to reduce the range of possible moves.

When dealing with novel information, knowledge may be unavailable to sufficiently limit the range of possible moves. Instead of using knowledge to reduce the range of moves, the *narrow limits of change* principle is used. Our limited capacity, limited duration working memory prevents us from attempting to generate a large number of complex moves.

Lastly, the *environmental linking and organizing* principle uses information from long-term memory to alter the characteristics of working memory. Indefinite quantities of organized information held in long-term memory can be transferred to working memory for indefinite periods. As a consequence, information held in long-term memory transforms a working memory that is limited in capacity and duration into a working memory with no known capacity or duration limits. That information from long-term memory determines how we interact with our environment.

This cognitive architecture is used by cognitive load theory to generate instructional procedures. The aim of instruction, based on the *information store* principle, is to accumulate knowledge in long-term memory. Once stored, the *environmental linking and organizing* principle allows us to use the information to function in our environment. Knowledge stored in long-term memory is most easily acquired from other people using the *borrowing and reorganizing* principle. If knowledge held by others is unavailable to us, it can be created using the *randomness as genesis* principle. In both cases, the *narrow limits of change* principle indicates that instruction needs to minimize an unnecessary working memory load.

The cognitive load (or working memory load) imposed by instructional material depends on the number of elements (or schemas) with which learners must simultaneously deal. If elements interact, they must be dealt with simultaneously by working memory. Interacting elements that are intrinsic to the instructional material impose an intrinsic cognitive load that cannot be reduced other than by changing the nature of the task or by learning to group elements together into a higher-order schema that acts as a single element. Interacting elements that are extraneous to the instructional area impose an extraneous cognitive load that should be reduced by altering instructional procedures. Working memory resources devoted to dealing with intrinsic cognitive load are germane to the task at hand and are sometimes referred to as germane cognitive load. Effective instruction maximizes working memory resources dealing with intrinsic cognitive load that is germane to the task at hand and minimizes working memory resources dealing with extraneous cognitive load.

Cognitive load theory has been used to generate many instructional effects using randomized, controlled experiments comparing various instructional procedures. These are described in the next section.

Important Scientific Research and Open Questions

The *worked example* effect is demonstrated when studying worked examples increases problem-solving skill more than solving the equivalent problems. Searching for problem solutions using the *randomness as genesis* principle imposes a heavy, extraneous cognitive load that reduces learning. In contrast, studying worked examples makes use of the *borrowing and reorganizing* principle. Skilled problem solvers have learned to recognize problem states and the best move for each state. Worked examples are ideally suited to indicate which moves are best for particular problem conditions.

The *problem completion* effect is related to the worked example effect. Instead of learners being presented with fully worked examples, they are presented with partially completed worked examples that they must complete themselves. Characteristically, learners who complete partially completed problems learn more and perform better on subsequent tests than learners who solve full problems, demonstrating the problem completion effect.

The *split-attention* effect occurs when learners must split their attention between multiple sources of information that are unnecessarily presented in physically separate form. For example, an explanation associated with a diagram may be presented next to the diagram rather than at appropriate points on the diagram. Learners must mentally integrate a text and diagram that are physically separate and mental integration requires working memory resources that consequently are unavailable for learning, imposing an extraneous cognitive load. Placing text at appropriate points on a diagram allows working memory resources to be used for learning instead of relating the two sources of information. The split-attention effect occurs when physical integration is superior to mental integration. The effect requires the two sources of information to be unintelligible in isolation. If, for example, text merely redescribes a diagram, the split-attention effect will not be obtained (see the *redundancy effect* below).

The *modality effect* is demonstrated by comparing information presented in both visual (e.g., a diagram) and spoken (text) modes to information presented in a visual mode only with written text. The effect occurs when a dual, audio-visual mode of presentation is superior to a single, visual only (with written text) mode of presentation. The modality effect is related to the split-attention effect in that both effects require one or more sources of information to be unintelligible in isolation. The effect occurs because working memory capacity and learning can be increased by using both auditory and visual processes. The effect will not be obtained if the information includes long textual passages. These passages must be presented in written form because it may not be possible to process them appropriately in working memory.

The *redundancy* effect occurs when multiple sources of information are unnecessary for understanding, unlike the split-attention and modality effects that only occur when each source of information is essential. Unnecessary information must be processed in working memory and so imposes an extraneous cognitive load that is eliminated by eliminating the redundant information. The effect is obtained when learning is enhanced by the elimination of redundant information.

The *expertise reversal* effect is obtained when instructional procedures that facilitate learning by novices reduce in their relative effectiveness as levels of expertise increase. Instructional procedure A may result in more learning that procedure B for novices but for more knowledgeable learners, B may be superior to A. This effect is an outcome of the redundancy effect.

Information critical for novices may be redundant for experts and so impose an extraneous cognitive load. There are many versions of the expertise reversal effect depending on relations between the categories of information. One version is particularly important and is discussed next.

The *guidance fading* effect is an example of the expertise reversal effect that is dependent on the worked example and completion effects. Worked examples only are effective in comparison to solving problems for novice learners. With increasing expertise, the relative effectiveness of worked examples decreases and eventually reverses. For more expert learners in an area, studying worked examples is redundant and learning may be facilitated if worked examples are replaced by completion problems. As expertise increases further, even completion problems may be redundant and should be replaced by full problems. In this manner, the information provided to learners is faded from worked examples to completion problems and finally, to full problems as relevant information is stored in long-term memory and so becomes redundant if provided during instruction.

The *imagination* effect occurs when learners who imagine concepts or procedures learn more than learners who study those concepts or procedures. Imagining requires rehearsal of concepts or procedures in working memory, a procedure that can better transfer information to long-term memory than simply studying. The imagination effect is obtained when learners asked to imagine concepts or procedures learn more than learners asked to study the same concepts or procedures.

The *goal-free* effect is obtained when learners are presented the givens of a problem without the goal and asked to make as many problem moves as they can without reference to a goal. Conventional problems with a conventional goal require problem solvers to consider their current problem state, the goal state, differences between the two, and possible moves to reduce those differences. Under goal-free conditions, problem solvers only need to consider whether any move can be made. The reduced working memory load enhances learning compared to solving conventional problems. This technique only is likely to be effective using problems for which the number of moves that can be generated from the givens without a goal is very limited.

The *element interactivity* effect depends on intrinsic cognitive load. For effects dependent on reducing extraneous cognitive load (all of the above effects), intrinsic cognitive load must be high. If intrinsic cognitive load is low due to low intrinsic element interactivity, reducing a high extraneous cognitive load may not matter because total cognitive load may be below working memory limits. Cognitive load effects require complex information.

The *isolated-interacting elements* effect can be obtained if element interactivity due to intrinsic cognitive load is too high for working memory to process the information. Element interactivity and its attendant working memory load can be reduced by initially presenting the interacting elements as though they are isolated without reference to the interactions between them before presenting them in fully interacting form. Presenting information in isolated followed by interacting form facilitates learning compared to only presenting the information with all interactions between elements emphasized.

The *variability effect* also depends on variations in intrinsic cognitive load. If learners are presented new material with examples that vary in many surface characteristics, they must not only learn a new concept or procedure, they also must learn to extract the concept or procedure from the surface structure in which it is embedded. Intrinsic cognitive load is likely to be high. It can be lowered by reducing the surface variability but then learners no longer learn to distinguish between different surface variations. Providing there is sufficient working memory capacity to handle the increased element interactivity, high variability examples will result in more learning and transfer than low variability examples.

These effects, generated by cognitive load theory, indicate instructional procedures that can facilitate learning. The theory emphasizes the storage of large amounts of biologically secondary information in long-term memory after processing in a limited working memory. Stored information governs expert performance. Novel information is best obtained from other people. Cognitive load theory assumes that during instruction, learners do not acquire very general cognitive strategies because general strategies are biologically primary and so learned easily and automatically. Rather, the function of instruction is to assist in the acquisition of a large number of domain-specific, biologically secondary knowledge structures.

Cross-References

- ► Cognitive Load Measurement
- ► Goal-Free Effect
- ► Guidance-Fading Effect
- ► Imagination Effect
- ► Modality Effect on Learning
- ► Redundancy Effect on Learning
- ► Split-Attention Effect on Learning
- ► Worked-Example Effect

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Cognitive Lock-In

► Cognitive Automatisms and Routinized Learning

Cognitive Map

Internal representation of spatial relationship between cues within the environment.

Cognitive Mapping

► Spatial Learning

Cognitive Model Representation

► Mental Models

Cognitive Modeling

► Adaptive Game-Based Learning

Cognitive Modeling with Multiagent Systems

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Synonyms

Adaptive agents; Artificial life; Evolutionary robotics; Embodied agents

Definition

The computational modeling of cognition highly benefits from the use of computer models of the learning of behavioral and cognitive capabilities in simulated agents, such as for language development and evolution, or for the development of sensorimotor skills. Through the simulation of the dynamics and interactions in groups of agents it is possible to investigate the role of social and group-based processes contributing to the development of cognition. In addition, multiagent systems can be used to investigate phylogenetic processes affecting the evolution of cognitive capabilities. Examples of multiagent systems methodologies used for the study of cognition are artificial life models and evolutionary robotics. The main areas of investigation in this field are language learning and sensorimotor strategy development.

Theoretical Background

Cognitive modeling through agent-based systems permits the development and testing of specific hypotheses on the ontogenetic and evolutionary acquisition of behavioral and cognitive capabilities. Through the use of multiagent systems it is possible to investigate, with computer simulations, the role of social and group-based processes in the development of cognition. In particular, researchers can adopt a *synthetic modeling strategy* (Cangelosi and Parisi 2002; Langton 1997), which is quite different from classical scientific methodologies based on the analytic approach. For example, in the natural sciences such as biology, a top-down approach is often used by assuming the analysis, i.e., division, of the global biological system into its main component (e.g., the body is analyzed as a set of functional systems and organs). In linguistics, language is analyzed, i.e., decomposed, into syntax, words, phonemes. On the contrary, a synthetic modeling approach to cognition uses a bottom-up strategy to reconstruct the behavioral and cognitive system. The researcher can define the basic components of a cognitive agent, the rules by which these components interact, and the environment in which the agent and its components interact with each other. The computer program will then simulate the interactions among the components to observe the emergence of the various higher-level capabilities. With a simulation model, the feasibility and validity of assumptions regarding the components, their interaction rules, and the environment can be tested. For example, wrong, incomplete, or inadequate assumptions will make it impossible to observe the emergence of higher-level entities or of entities that do not have realistic properties and do not exhibit realistic phenomena. The bottom-up approach of synthetic simulations of multiagent cognitive systems also permits the study of problems and phenomena that are analytically intractable, such as those of complex and nonlinear systems, as it is the case of the phylogenetic and ontogenetic development of cognition.

Within the field of cognitive agent modeling, two main *synthetic modeling methodologies* have been employed: (1) artificial life models and (2) evolutionary robotics. *Artificial life* refers to the synthetic modeling of natural and artificial life-like systems, an innovative approach developed by Langton and collaborators in the late 1980s at the interface between biology and computer science (Langton 1997). Although part of the initial efforts within artificial life focused mostly on the modeling of plant systems (e.g., Lindenmayer systems) and low-level biochemical interactions (e.g., protein binding), artificial life systems have been extensively used for the modeling of behavioral and cognitive capabilities in multiagent systems (Cangelosi and Parisi 2002; Steels and Belpaeme 2005). These agent-based artificial life models typically consist of the simulation of a group of agents that have to survive by adapting to the social and physical requirements of the environment and have to reproduce through genetic algorithms. Common artificial life tasks regard navigation and exploration of the environment, social cooperation, and communication. The behavioral and cognitive capabilities of each agent are controlled using a variety of methods, such as artificial neural networks, that permit the modeling of learning mechanisms, as well as the interaction between evolutionary dynamics and ontogenetic learning processes.

Evolutionary robotics regards the autonomous design of the controllers of (simulated or physical) robots through the use of genetic algorithms (Nolfi and Floreano 2000). This robotics approach can be considered as a subset of the artificial life methodologies, with an additional focus on the role of embodiment in cognition due to the simulation of the robot's sensorimotor system. Although great part of the early work in evolutionary robotics focused on low-level sensorimotor capabilities (navigation, object avoidance, foraging), more recent work has extended the use of this methodology for higher-order motor and cognitive capabilities such as object manipulation and language learning. In addition, evolutionary robotics has been recently applied to more complex models of robotic platforms, moving from the use of simple wheeled robots to humanoid robot platforms. In addition, evolutionary robotics has also been used to develop models of the evolution of morphology of both the body and the brain of the agents.

If we consider the main areas of cognition that have been investigated through both approaches in multiagent systems, we can identify five main behavioral and cognitive capabilities where important scientific insights have been produced:

- *Navigation, exploration, and foraging strategies.* This is the area where evolutionary robotics, as well as early artificial life models, has contributed most (Nolfi and Floreano 2000). These studies typically used wheeled robots (khepera, e-pucks) to investigate the evolutionary emergence of flexible, adaptive strategies for optimal exploration strategies and foraging. Models demonstrated the strict coupling between the agent's own sensorimotor system and of the constraints of their environment.
- *Categorization.* The adaptive interaction with the environment requires the capability to categorize the objects and entities in the world, consistently with the agent's own internal needs and social context. For example, Steels and Belpaeme (2005) analyzed which mechanisms a population of autonomous agents benefits from to arrive at a repertoire of perceptually grounded color categories. They compared three main approaches to human categorization: nativism, empiricism, and culturalism.

Multiagent simulations showed that the collective choice of a shared repertoire must integrate multiple constraints, including constraints coming from communication.

- *Biological and cultural evolution of language*. Language is definitely one of the main areas where synthetic multiagent systems have produced significant impact and scientific explanations (Cangelosi and Parisi 2002). In particular, numerous models of the biological and cultural evolution of language have shed light on the crucial factors favoring the evolutionary emergence of languages, such as social learning phenomena and internal representation capabilities. More recently, such computer models have been put in relationship with empirical data on human languages (Vogt 2009).
- *Development and grounding of cognition in embodiment systems*. Language again has been used as a test case for investigating the role of embodiment in cognition. For example, Cangelosi (2010) uses a variety of multiagent systems to examine the grounding of language into the agent's own action repertoire, both in simulation agents and in humanoid robots. These models are consistent with increasing empirical evidence from neuroscience and cognitive psychology on embodied cognition.
- *Social coordination*. Synthetic multiagent models have been utilized to study social coordination (both competition and cooperative interactions) amongst groups of cognitive agents. For example, coevolutionary simulations on prey–predator competition experiments demonstrated an "arms race" phenomenon where increase in complexity in one population, e.g., escape strategies of the prey, can cause the emergence of complex strategies in the coevolving predator species (Nolfi and Floreano 2000).

Important Scientific Research and Open Questions

The field of synthetic multiagent systems has received an important boost in the last few years because of technological progress on computer simulation systems and robotic agent modeling. Thanks to advances in computationally intensive simulation tools for evolutionary and multiagent systems and to the availability of open-source physics engines, it is now possible to build more detailed and accurate models of cognitive agents (e.g., model of humanoid robots) and carry out extensive simulation experiments (e.g., on the evolution of brain and body morphology). In addition, the increasing empirical evidence in neuroscience and psychology on the embodiment bases of cognition opens new challenges for the understanding of the interaction between sensorimotor knowledge and other cognitive capabilities.

Such significant technological and scientific advances have opened up a series of new challenges in cognitive modeling through multiagent systems. Here we list a few of the key research questions for future research:

- How can more complex embodiment systems, such as simulation models of humanoid robots, be used to explain the fine mechanisms of the grounding of cognition (e.g., microaffordance effects of action–vision links, action-compatibility effects in language processing)?
- What are the evolutionary and developmental mechanisms that supported the coevolution of brain and behavior?
- How can multiagent systems be used to investigate the effects of different social interaction protocols in the establishment and maintenance of social structures?
- How can the current minimal cognitive models used in multiagent systems be scaled up to investigate higher-order cognitive capabilities?
- What are the interaction dynamics between genetic evolution and cultural evolution in the emergence of language?
- What is the role of evolutionary and cognitive factors in the emergence of syntax?

Cross-References

► Agent-Based Modeling
► Cognitive Models of Learning
► Cognitive Robotics
► Learning Agents and Agent-Based Modeling

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Cognitive Models of Learning

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Synonyms

Cognitive skill acquisition; Computational models of learning; Conceptual change

Definition

A cognitive model is a descriptive account or computational representation of human thinking about a given concept, skill, or domain. Here, the focus is on cognitive knowledge and skills, as opposed to sensorimotor skills, and can include declarative, procedural, and strategic knowledge. A cognitive model of *learning*, then, is an account of how humans gain accurate and complete knowledge. This is closely related to metacognitive reasoning and can come about as a result of (1) revising (i.e., correcting) existing knowledge, (2) acquiring and encoding new knowledge from instruction or experience, and (3) combining existing components to infer and deduce new knowledge. A cognitive model of learning should explain or simulate these mental processes and show how they produce relatively permanent changes in the long-term memory of learners. It is also common to consider *impoverished* cognitive models of learning which can be useful for diagnosis of learner errors and misconceptions, and in many cases, prescribing appropriate instructional interventions.

Theoretical Background

Cognitive modeling is a basic tool for the field of *cognitive science* used to account for human thinking for just about any imaginable context. A cognitive model for a given domain or problem solving task typically represents an expert's knowledge, which can sometimes take years (or even a decade) to form in the mind of that expert. For a learner seeking to become an expert in that domain, the developmental path to that desirable end state can be just as complex, if not more, than the domain knowledge itself. The tools of cognitive science can also be used to describe the processes learners engage to acquire knowledge and expertise in a given domain. To construct such cognitive models of learning, a variety of approaches are used to collect relevant data while students are engaged in learning. These include think-aloud protocols, problem solving traces, diagnostic tests, and even neurological analyses of brain activity. Because learning can occur in different ways, in different contexts, and for different knowledge types, a variety of models that account for learning have emerged. Further, cognitive models of learning can take a descriptive form reporting empirical observations and strategies revealed from learner thinkalouds to a more formal, computational form suitable for simulation on a computer (Ohlsson 2008).

Acquisition of cognitive skills is a common focus of cognitive models of learning. Here, learning is focused on solving problems in a given domain. Substantial empirical evidence exists showing that cognitive skill acquisition progresses in three stages: (1) *cognitive stage*: learners develop a declarative encoding of the domain knowledge, (2) *associative stage*: through practice, errors in knowledge are identified and repaired, and (3) *autonomous stage*: continued practice increases speed and accuracy during execution of the cognitive skill. Models of cognitive skill acquisition generally strive to follow the same pattern, and deal with the complexities that learners also face. They track learning of individual rules, or knowledge components, to multiple interacting pieces of knowledge at once, and finally, on to the final stages when practice produces autonomy (VanLehn 1996).

Cognitive models of learning are tied closely to metacognition, which can informally be understood as "thinking about thinking." Metacognitive thinking represents an essential aspect to cognitive models of learning because they define control mechanisms the learner must apply in order to actually acquire new knowledge. That is, to reach the end state of possessing usable and accessible new knowledge in long-term memory, learners must actively regulate their own cognitive processes, decide where to direct their attention, self-assess to decide if they understand, *self-explain* in order to establish connections between domain principles and the object of study, decide if they will seek help, and so on. For example, learners who study worked-out examples learn more effectively if they choose to frequently stop to check their own understanding and identify underlying principles that provide justification for problem solving steps (Chi et al. 1989). A good example of a computational model of these activities, along with other learning mechanisms, is captured in the computational cognitive model of learning, Cascade (VanLehn 1999). The model simulates learning from worked-out examples as well as from problem solving and produces cognitive changes on the *impasse–repair–reflect* cycle, a model derived from empirical studies of human learners (Chi et al. 1989). During learning, if Cascade finds that its current domain knowledge is insufficient to move forward in reading or problem solving (i.e., it is at an impasse), this triggers a *learning event*. The system seeks to modify its existing knowledge or add a new rule that will allow it to overcome the impasse (i.e., a repair). Finally, reflection is achieved via *explanation-based reasoning* on the proposed solution to determine correctness. In Cascade, the approach is to leverage commonsense knowledge in conjunction with existing knowledge to construct new rules for future use (VanLehn 1999, pp. 86–87).

Broadening the perspective beyond cognitive skill acquisition, researchers have also investigated cognitive models of *conceptual change* during learning and development. Here, models deal directly with the fact that learners enter into learning situations with preconceived and naïve conceptions and misconceptions about the world. Recent research on conceptual change has shifted focus to the learner by introducing *intentional* conceptual change, defined as "goal-directed and conscious initiation and regulation of cognitive, metacognitive, and motivational processes to bring about a change in knowledge" (Sinatra and Pintrich 2003, p. 6). These approaches therefore overlap significantly with metacognitive models of learning, but with substantially more of a focus on developmental and repair activities necessary for long-term conceptual understanding.

Important Scientific Research and Open Questions

Cognitive models represent an important class of tools in the study of human cognition and learning. To date, researchers have made incredible strides in studying and modeling complex human learning (Ohlsson 2008; VanLehn 1999). However, any model of human learning is almost by definition, incomplete. It is always necessary to restrict a cognitive model of learning in some way, whether it be the domain it operates on or the kinds of reasoning of which it is capable. Nowhere is this more evident than in recent efforts to integrate affective and emotional processes into models of learning (Kort 2009). Here, researchers are focused on understanding the interplay between emotion and learning to answer basic questions such as when instruction is most effective, at what point do learners respond positively to challenge, and when does frustration hinder or impede learning. These questions represent key open questions in both the psychological literature on human learning, as well as in the cognitive modeling literature. Ohlsson (2008) points out that an assumption made by many computational models of learning is that learning mechanisms are tested independently (p. 384). This suggests that as more models are tested for validity and completeness, they should be done so in complex learning contexts that involve multiple learning mechanisms. It is the interaction between learning mechanisms that may pose a hidden threat to the success of existing computational models of learning. In addition, research on emotions in learning processes can be viewed as a positive step because they are inherently contextual (i.e., learning is never focused on sitting down to simply experience an emotion – it always involves a cognitive target). Finally, very few cognitive models of learning have integrated findings from cognitive neuroscience, and so this represents a key open area of future research. To date, researchers have determined areas of the brain that are involved in learning, emotion, and automaticity. This empirical data may shed light on cognitive models of learning by providing evidence for setting of parameters (e.g., rate of learning or memory decay) and testing of underlying assumptions.

Cross-References

► ACT
► Cognitive Dissonance in the Learning Processes
► Cognitive Learning

▶ Cognitive Load Theory
▶ Computational Models of Human Learning
▶ Conceptual Change
▶ Developmental Cognitive Neuroscience and Learning
▶ Human Cognitive Architecture
▶ Metacognition and Learning

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Cognitive Neuroscience

The study of information processing that emphasizes the relationship between psychological processes and their neural substrates.

Cognitive Overload

▶ Effects of Multimedia Redundancy in History Learning

Cognitive Plasticity

▶ Mediated Learning Experience (MLE) and Cognitive Modifiability

Cognitive Pleasure

▶ Aristotle on Pleasure and Learning

Cognitive Processes

▶ Abilities to Learn: Cognitive Abilities

Cognitive Processing Speed

▶ Mental Chronometry

Cognitive Psychology

The study of the psychological processes that underlie information processing.

Cross-References

▶ Human Information Processing

Cognitive Psychology of Music Learning

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Synonyms

Psychology of Musical Thinking and Acting

Definition

Cognitive psychology of music learning is the study of the perceptive and generative processes involved in listening to, performing, analyzing, improvising, and composing music.

Theoretical Background

The Musical Brain

The human brain responds to musical stimuli throughout the lifespan. Infants process musical auditory skills and remember music they hear. Development of musical abilities follows a developmental trajectory. Both genetic predispositions and early instruction experiences affect the development of the musical brain. Contextual influences, such as parent support, as well as intrinsic motivation factors determine the extent to which an individual becomes a musician.

Musicians who began receiving music instruction at an early age have different brain structures when compared to individuals who never received instruction. Moreover, musicians exhibit different electrophysiological brain responses while performing different tasks. Regardless of differences in brain structure, the underlying processes that govern how we perceive, process, and respond to musical stimuli is the same for musicians and nonmusicians.

Musical activity encompasses every part of our brain. Different parts of the brain process different elements of music, such as timbre, beat, rhythmic patterns, tonalities, harmonies, song lyrics, and so on. Different parts of the brain are interconnected and dependent on each other when attempting to categorize incoming musical stimuli, using memory, reasoning, and evaluation. A variety of factors determine how brain mechanisms work in the case of evaluating and responding to music.

We evaluate music based on our previous experiences. Through musical experiences our brain learns to associate different sounds as pleasant, soothing, calming, or arousing. As we listen to music, our brains work quickly to categorize and impose structure over the incoming stimuli. This process is ongoing because the feedback we receive from our brain subsequently becomes a factor determining how we respond and evaluate future musical stimuli. Gradually our brain develops a complex system of expectations that helps us understand musical genres, harmonies, and rhythmic or tonal patterns.

Musical compositions are designed around validating or violating our expectations. Our familiarity with specific musical genres determines whether our brain will interpret a piece as simple or complex. An individual who has heard jazz music throughout his or her life will have a different evaluating response when hearing a jazz composition in comparison to an individual who has only heard jazz music sporadically.

Music Learning and Cognition Learning Theories

Theories of the development of musical learning include both a thinking component – cognition – and a learning component. The learning component is experiential in nature. Musicians grow in both knowledge and experience. The next sections briefly describe the essential general learning theories, in the context of music learning.

Behaviorism. Adherents to this theory of musical learning believe in the power of classical conditioning. Classical conditioning, developed by Pavlov in his experiments with dogs, revealed that a neutral stimulus will elicit a response after repeatedly being paired with another stimulus that already elicits that response. Stimulus-response chains can then be developed that will lead to predictable, generalizable behaviors. Examples of behaviorism in music teaching and learning can be found in the area of traditional instrumental music education. Wind bands practice for festivals, where they receive ratings that reinforce or inhibit their behaviors. On a smaller level, instrumentalists' musical practice habits can be reduced to a series of behaviors that researchers who espouse to this theory of learning can describe and measure quantitatively. Examples of behaviorism in music therapy include using music as a contingency for modifying behavior or as a cue for teaching new skills. Jayne M. Standley and her research with premature infants, Clifford K. Madsen, and Alice-Ann Darrow are examples of researchers firmly grounded in Behaviorism.

Cognitive Psychology. Cognitive psychology, specifically, in music learning theory was a shift from the focus on observable measurable behaviors to a focus on examining internal processes of cognition and intellectual growth. *Constructivism* is a branch of cognitive psychology grounded on the principle that all individuals are born with certain cognitive functions, and that these cognitive functions develop over time. So, each cognitive function builds on previous age-based and/or experience-based versions of that particular function. Jean Piaget is probably the most influential figure in this line of research. Within the music learning area, researchers such as Mary Louise Serafine and her *Generative Processes* theory, and Edwin Gordon and his *Music Learning Theory* are examples of researchers in music education firmly grounded in Cognitive Psychological theory. Kenneth Aigen is a music therapy researcher who has applied Serafine's theory to explain client responses in music therapy.

Sociohistorical Theory. Proponents of the sociohistorical theory of learning emphasize the importance of context and history in the development of all manifestations of learning, including both cognitive and experiential. Through this theoretical lens, researchers such as Vygotsky have proposed that learning does not center entirely on the solitary actions of individuals, as the behaviorists would imply, or on the interaction between the individual and his or her environment as the constructionist would imply. Rather, sociohistorical theorists see all human learning as occurring within particular cultures, with particular histories. Vygotsky's work in sociohistorical theory can be seen in the music education literature in the work of Patricia Shehen Campbell and others. In music therapy, Mercédès Pavlicevic, Gary Ansdell, and Brynjulf Stige are prominent researchers influenced by sociohistorical theory.

Connectionism. Connectionist theorists use innovative technology such as electroencephalography (EEG), electromagnetic-encephalography (EMG), event-related potential (ERP), magnetic resonance imaging (MRI), computer tomography (CT), and positron emission tomography (PET) to measure activity in the brain when individuals are engaged in musical activities. Neural networks provide the basis for an individual's musical representations. Learning within this theory is then related to physiological conditions of the brain. Notable pioneer researchers within this area of music learning area are Donald Hodges, John Flohr, Daniel Miller, and Diane Persellin. In music therapy, Michael H. Thaut is a prominent researcher who developed Neurologic Music Therapy, a scientific model of examining the therapeutic uses of music in neurologic rehabilitation, neoropediatric therapy, nerogeriatric therapy, development, and adaptation.

Important Scientific Research and Open Questions

Measurement of Musical Abilities. The measurement of various musical abilities have been examined in research, including: performance, improvisation, and composition. *Performance* – practice habits and motivation have been explored recently in the area of musical performance. The function of family support to the practicing musician has been a component of that research. Performance practice has been considered almost exclusively in terms of Western Classical music-making. Future research might examine practice in terms of non-Western Classical music-making: ethnic ensembles, popular music ensembles, and new-music ensembles. *Improvisation* – constraints imposed on the process of improvisation has been a topic of research. The measure of musical ability and improvisation has been examined most notably in jazz. Researchers have examined group improvisation as a social construct, one where individual identities are shaped by participation in the group. Future work in this area could include examining how an identity as an improviser in a group is different than an identity as a performer. *Composition* – work in the area of composition learning has focused on processes, products, and the meaning of composition to individuals. There is a focus currently on understanding composition learning in particular teaching and learning contexts. Future work could probe qualitatively the value and meaning of composition learning to students.

Perception of Musical Sounds. A number of different areas have been examined in the area of music perception. Researchers have focused their efforts on understanding the perception of pitch, tonal cognition, musical timbre, musical time (meter and rhythm), and musical memory. This line of research has blossomed alongside the multiple technological innovations that have made measurement in this area more feasible.

Music Cognition and Psychobiology. Empirical studies examining how music cognition and the aesthetic qualities of music affect cognitive, affective, sensory, and motor human responses are continuing to emerge in the music therapy literature. Such findings continue to inform clinicians who use biomedical applications of music in therapy or music as therapy.

Cross-References

► Human Cognitive Architecture
► Shared Cognition
► Situated Cognition

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Cognitive Restructuring

► Cognitive-Behavioral Family Therapy

Cognitive Robotics

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Synonyms

Cognitive systems; Developmental robotics; Epigenetic robotics; Humanoid robots; Neuro-robotics

Definition

Cognitive robotics, also known as artificial cognitive systems research, regards the use of bio-inspired methods for the design of sensorimotor, cognitive, and social capabilities in autonomous robots. Other designations have been proposed in the short history of cognitive robotics which spans approximately the last 15 years, as for example, Epigenetic Robotics, Autonomous Mental Development (AMD), or Cognitive Developmental Robotics (CDR). Robots are required to *learn* suchcapabilities (e.g., attention and perception, object manipulation, linguistic communication, social interaction) through interaction with their environment and via incremental developmental stages. The biological- and cognitively inspired methods and design principles are derived from studies in cognitive and developmental psychology, and neuroscience. In addition to the technological aim of designing autonomous robots, cognitive robots are also widely used as embodied computational models investigating the organization of learning and cognition within the cognitive and neural sciences. A growing field of cognitive robotics has taken a developmental (i.e., ontogenesis) flavor in recognition of the fundamental role of learning in the final performance of biological cognitive systems.

Theoretical Background

In the fields of cognition, neuroscience, and robotics there is growing theoretical and empirical evidence on the role of embodiment, situated learning, and the grounding of cognitive capabilities in sensorimotor knowledge in natural and artificial cognitive systems (Pfeifer and Bongard 2006). Recent advances in cognitive psychology, neuroscience, cognitive linguistics, and developmental psychology support an embodied view of cognition, i.e., the fact that cognitive functions (e.g., perception, categorization, reasoning, and language in particular) are strictly intertwined with sensorimotor and emotional processes (Rizzolati and Craighero 2004). This is particularly evident in numerous experimental psychology studies on the grounding of language, and other cognitive capabilities, in action and perception.

Such evidence is consistent with cognitive robotics research. This uses knowledge from neural and cognitive sciences to derive bio-inspired design principles for cognitive development that are then tested in robotic platforms. The training of a robot to acquire sensorimotor, cognitive, and social capabilities implies that these skills are developed through dynamic interactions between the entire cognitive system and its environment. As such, most studies in cognitive robotics require the simultaneous learning of several cognitive skills, although a certain progression can be identified by studying human cognitive development (von Hofsten 2004).

Within the field of cognitive robotics, in fact, the developmental (epigenetic) robotics approach focuses on the autonomous mental development of cognition through incremental and maturational stages (Weng et al. 2001; Lungarella et al. 2003). Such an approach is directly inspired by ontogenetic stages studied in developmental psychology, as in Piaget's epigenetic psychology. Development adds an important aspect to the study of cognitive robotics by considering the possibility that cognitive skills arise only through a process of maturation rather than being fixed and hand-coded a priori by a human designer. Typically, developmental robotics attempts at identifying a small number of early behaviors (the inductive bias) and the rules of development that transform the early behaviors in new skills via interaction of the cognitive agent with the environment (including social interaction).

The main areas of research in cognitive and developmental robotics regard the following topics:

- Curiosity, attention, vision. The development of humans is driven by motives that can be social (interaction) or even motoric (it seems that exercising the motor system is a strong motive by itself). This is important since cognition develops at the interface between the brain and action but requires goals and a motivated subject (von Hofsten 2004). Attention and more in general vision clearly shape profoundly the acquisition of cognitive skills. In robotics, many of these skills and their developmental counterparts have been modeled and this represents one of the main trends in cognitive robotics. For a review of the relevant literature, the interested reader is redirected to Lungarella et al. (2003) and Vernon et al. (2007).
- Manipulation. Tantalizing results from neuroscience have shed light into the intricacy of the control of manipulation in the brain (Rizzolati and Craighero 2004). Many examples of the cognitive control of manipulation (comparing this to more traditional model-based manipulation) have been proposed, often at the boundary of imitation and social interaction as an attempt to explain not only the how (that is the realm of neuroscience) but also the whys of certain brain circuits. One pivotal discovery is clearly that of mirror neurons (Rizzolati and Craighero 2004 for a review) which has generated consistent interest in the cognitive robotics community (see Arbib et al. 2008).
- Communication and language. Language learning is one of the key research topics in cognitive robotics as it provides a prototypical example of how higher-order cognitive skills (semantics, syntax) are directly grounded on sensorimotor knowledge. For example, Cangelosi and Riga (2006) developed an epigenetic robotics model of language grounding. A simulated robot is first trained to learn, by imitation, a set of action primitives, and a corresponding set of action words describing these motor categories. Subsequently, the robot is taught linguistic combinations of the names of actions to describe compositional, higher-order actions (e.g., "grab" as a result of the simultaneous use of the left and right arms). Through a symbol grounding mechanism, implemented in the robot's own neural architecture, the robot is then able to transfer the grounding of basic action words to higher-order compositional actions. This simulation model is currently being extended to language learning experiments with the iCub robot.
- Social interaction, imitation, and cooperation. Great part of early work on cognitive humanoid robotics has centered on imitation and social learning (Schaal 1999). This is also explained by developmental psychology focus on learning by imitation from parents and peers and its importance for social development. Social learning and imitation studies have proposed models of learning by imitation (e.g., imitation of motor behavior from a teacher or demonstrator) as well as social learning for higher-order cognitive capabilities (e.g., perspective-taking).
- Locomotion. There is consistent developmental literature that locomotion in humans opens up the doors of spatial understanding. Numerous experiments show that certain perceptual judgments develop in tight synchrony with the development of crawling (or more in general with the ability to move in the environment). Robotic research in this direction concentrated though mostly in the technical skills (motor control) required for standing and walking (e.g., Asimo) rather than in the cognitive aspects connected with walking. Furthermore, most of this same research does not consider a developmental progression (Thelen and Smith 1994) and rather addresses the problem of the generation of suitable trajectories and feedback stabilizing controllers.

Cognitive Robotics Platforms

In the literature there is a variety of robotics platforms, using different actuators configurations (mobile robots, arm manipulators, humanoid), that have been employed for cognitive modeling research. However, humanoid robots provide a more general and suitable test platform for cognitive robotics as they permit the investigation of complex sensorimotor capabilities (e.g., object manipulation) and realistic human–robot interaction (HRI) scenarios. The humanoid platforms most commonly used in cognitive robotics are the iCub (RobotCub Consortium), Qrio (Sony Corp.), AIBO (Sony Corp.), Asimo (Honda), and NAO (Aldebaran robotics).

The humanoid robot iCub (Sandini et al. 2007) is one of the platforms gaining significant impact in cognitive and developmental robotics. The iCub has been developed as part of the RobotCub EU project (IST FP6 004370) with the explicit goal of providing a complex platform for cognitive systems research. With this in mind, the iCub was designed with complex hands for manipulation (9 degrees of freedom each), facial expressions (for interaction), and locomotion abilities (crawling). Sensors are also important and in this respect, the iCub sports cameras, microphones, gyroscopes, accelerometers, position sensors of various types, and a sensorized skin. The platform is distributed as Open Source following a GPL license in an attempt to make it the platform of choice for research in cognitive systems. About 20 iCubs have been built as part of this endeavor. This allowed the creation of a community of users and the possibility of sharing results or building on each other's success.

One important aspect of the availability of such complex platforms at many locations is the possibility of benchmarking and experimental validation. Experiments and models can be now truly tested on the same hardware and results compared quantitatively. In a sense, the dependence on the platform becomes less important since many share the same platform (the iCub).

Important Scientific Research and Open Questions

Open research questions in cognitive robotics regards the following topics:

- Cognitive architecture. As Vernon and colleagues (2007) point out, the term Cognitive Architecture was precisely defined as early as the seminal work of Newell and Simon (1976). For classical AI systems, the Cognitive Architecture represented the invariant aspects of the cognitive system and those that are independent from the task. Provided with knowledge, the cognitive architecture was theoretically capable of performing a given task. Conversely, for embodied and developmental systems the definition of a Cognitive Architecture is less clear. One attempt of a definition as proposed in the above mentioned paper by Vernon et al. identifies the Cognitive Architecture of a developmental system as its phylogeny. In this respect, the Cognitive Architecture contains the initial skills of the system together with its developmental rules.
- *Interaction between development, maturation, and phylogeny.* Within cognitive robotics, most of the focus has been on incremental (i.e., developmental, ontogenetic) learning. On the other end, other approaches such as evolutionary robotics mostly focus on phylogenetic changes. Future research should look at the interaction between such phenomena (as in the Baldwin effect) and the interaction with neural and morphological maturational mechanism, known to affect learning and development.
- *Robustness in unstructured environment.* One of the main challenges that cognitive robotics aims to address, in comparison with classical robotics approaches such as industrial automation, is the capability of robots to adapt to dynamic and unpredictable environments. This is the case for example of humanoid robots that have to operate in open and unstructured environments (e.g., walking in home, table-top manipulation tasks).
- *HRI and social acceptance.* The increasing availability of humanoid and mobile robots in service robotics, such as companions for elderly, has important implications for defining users' acceptability criteria to facilitate human–robot interaction.

Cross-References

► Agent-Based Modeling
► Cognitive Modeling with Multiagent Systems
► Cognitive Models of Learning
► Learning Agents and Agent-Based Modeling

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Cognitive Skill Acquisition

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Synonyms

Learning by doing; Learning by practicing

Definitions

The term “skill” refers to the ability to perform a multistep task such as tying one’s shoelaces, using an electronic device, or proving an algebraic theorem. Successful performance requires knowledge about which actions are relevant, under which circumstances those actions should be performed, how they relate to the person’s goal, and what their effects are likely to be. This type of knowledge is variously referred to as “competence,” “expertise,” “know-how,” “practical knowledge,” “procedural knowledge,” and “skill knowledge.” No single term is standard; *practical knowledge* will serve.

Practical knowledge is intrinsically related to goals and actions, while *declarative knowledge* consists of facts, episodes, and generalities that are true or false independent of a person’s intentions or behavior (e.g., *the Earth is round*). Practical knowledge is primarily acquired via practice, while declarative knowledge is primarily acquired via observation and discourse. A popular belief holds that the two types of knowledge follow different forgetting curves, with declarative knowledge (e.g., the content of a text) decaying faster than practical knowledge (e.g., the skill of riding a bicycle), but this belief is not grounded in research.

Cognitive skills are exemplified by symbolic activities like chess and mathematics and by professional activities like medical diagnosis, computer programming, and ship navigation. Successful performance depends primarily on the processing of conceptual information. In contrast, *motor* skills (a.k.a. “perceptual-motor skills” and “sensori-motor skills”) are exemplified by tasks such as baseball, dance, and juggling. Successful performance depends primarily on the physical characteristics of the person’s movements: acceleration, amplitude, direction, force, speed, timing, and so on. The boundary between the two types of skill is not sharp.

Theoretical Background

The study of cognitive skill acquisition began in the late nineteenth century with the work of Edward Thorndike, who studied how animals learned to escape from problem boxes, and by W. L. Bryan and N. Harter, who studied the growth of skill in telegraph operators. A review by Robert Woodward in 1938 summarized 27 relevant studies. The behaviorist school of psychology that dominated learning research in the 1913–1956 period developed many of the experimental methods for the study of learning that are still in use and discovered the implicit learning of statistical regularities (e.g., probability matching). During World War II, psychologists worked with natural scientists and technologists who developed the first information technologies, including feedback systems. Information processing concepts revolutionized cognitive psychology, but they were initially applied to other problems than learning. In the 1960s, applied psychologists like P. Fitts, R. Gagné, and A.T. Welford developed the enduring notions of learning curves, phases of practice, and multiple modes of learning, The modern study of cognitive skill acquisition began with a 1979 article by Y. Anzai and H.A. Simon that reported a computer simulation of the acquisition of a problem solving skill in a single subject.

The essence of practice is to attempt to perform a *target task* that one has not yet mastered, with the intent to master it. Each attempt at performing the task is a *training trial*, or *trial* for short. The learner's behavior changes gradually over trials: The learner makes fewer erroneous or unnecessary steps, hesitates less, and executes the appropriate actions faster. These changes can be represented by a *learning curve* (a.k.a. "practice curve"): If performance, measured, e.g., by the time for task completion, is plotted as a function of the amount of experience with the target task, measured, e.g., in terms of number of trials, the result is invariably a negatively accelerated curve. That is, the rate of improvement is fastest in the beginning, slows down as practice progresses, and eventually approaches an asymptote that represents the best possible performance. There is disagreement about the best mathematical description of such curves, but the negatively accelerated shape of empirical learning curves is one of the most thoroughly documented regularities in the study of learning. An accurate theory must account for this phenomenon. However, it turns out that negatively accelerated learning curves can be derived from several different theoretical assumptions, so this test is less stringent than it first appears.

A variety of cognitive mechanisms have been proposed to explain the basic practice effects. It is useful to organize these by the phase during practice when they are most likely to be active:

1. The *initial phase* lasts from the first encounter with the target task until the task has been completed for the first time. Cognitive mechanisms that are likely to operate during this phase include the internalization of task instructions, if any (a.k.a. "proceduralization" and "knowledge compilation"); the use of analogies to already mastered tasks; the study of solved examples and demonstrations, if available; reasoning from prior declarative knowledge; and capturing positive outcomes of heuristic search (a.k.a. "trial and error").
2. The *mastery phase* lasts from the first complete performance until the correct performance can be reliably produced. The cognitive mechanisms that are likely to be important during this phase include learning from the feedback (a.k.a. "knowledge of results") provided by the task environment (see below).
3. The *optimization phase* begins when the task has been mastered and lasts as along as the learner continues to perform the task. The cognitive mechanisms that are likely to operate during this phase include the discovery of new, qualitatively different strategies; the identification of redundancies and shortcuts; the optimization and speedup of actions and cognitive operations; and the replacement of multistep processes with retrieval from memory of repeatedly produced answers.

The observable effects of practice – fewer errors, faster performance – are cumulative effects of the interactions among the multiple learning mechanisms. The three phases should not be seen as sharply bounded. They represent gradual shifts in the relative importance of different mechanisms as practice progresses.

Important Scientific Research and Open Questions

1. Feedback. The term "feedback" is imported from engineering. In the study of cognitive skill acquisition, *positive feedback* (a.k.a. *positive reinforcement*) is information to the effect that an action taken by the learner was appropriate, correct, or useful, while *negative feedback* (a.k.a. *negative reinforcement*) is information to the effect that the learner's action was inappropriate, incorrect, or unhelpful. Feedback is sometimes intrinsic to a task environment (e.g., error messages in computer software), but a coach, supervisor, teacher, trainer, or tutor can support skill acquisition by delivering additional feedback in the course of practice. The two central questions are

when, under which circumstances, a tutor should intervene, and what information should be included in a feedback message.

Immediate feedback is more helpful than delayed feedback. Other aspects of feedback have turned out to be less straightforward. If feedback helps, it seems to follow that more feedback should help more. In some studies, increasing the frequency of feedback resulted in more effective learning. But in others, higher feedback density appears to impair learning. With respect to content, some studies show that bare bones feedback ("yes/no" or "right/wrong") is less effective than feedback with explanations ("*this answer is wrong, because...*"), while other studies have found no advantage for the explanatory content. Both positive and negative feedback can be helpful, but if the learner interprets negative feedback as punishment, it is likely to have an adverse effect on motivation. Even when feedback is purely informational, results vary. Some studies show strong effects of negative feedback, while others do not. Common sense suggests that negative and positive feedback in combination is more helpful than either in isolation, but this assumption has no extensive research support.

The problem of feedback is central to the design of *intelligent tutoring systems*, educational software systems that use artificial intelligence techniques to compute on line the feedback to be delivered to the learner. Tutoring systems are more helpful than independent practice or lectures but less helpful than human tutors. The effort to design more helpful tutoring systems would benefit from more decisive research on the effects of different feedback variables. The possibility of accessing tutoring systems via the Internet suggests that their importance will grow over time.

2. Transfer. The finding that cognitive skills become more adapted to the particulars of the target task during practice raises the question of how a mastered skill can be applied (transferred) to tasks that differ in their details from the training task. Effective performance requires high specificity, while broad application requires abstraction. Yet, people tend to be both effective and flexible in their everyday behavior. Abstract declarative knowledge, anticipation of the future situations in which a skill is to be applied, the hierarchical structure of strategies, and the encoding into memory of a large number of particular cases have all been proposed as possible sources of flexibility. It is widely believed that varied problem solving experience is more likely to foster transferable skills than drill on very similar practice tasks. It is also widely believed that conceptual understanding of why a particular strategy works facilitates application of a strategy to unfamiliar situations. Neither belief is strongly supported by research. Due to the intrinsic contradiction between effectiveness and generality, it is unlikely that the transfer problem has a principled solution.

   The problematic consequence for school learning is that there is no way to ensure that skills learned in a classroom will be applied outside school. In vocational and professional training situations, the standard solution to this problem is to trade off generality for effectiveness and conduct training in so-called *high-fidelity training environments*. These are designed to be as similar to the future application environment as possible. Examples include flight simulators for airline pilots and simulated battlegrounds for the military. Virtual reality technology makes this training strategy more widely applicable.

3. Long-term practice effects. As practice progresses over long time, the consequences depend on the type of skill and the characteristics of the training. A simple skill performed over and over again with little variation – a.k.a. *drill* – becomes *automatized*. Automatized skills (a) are triggered when appropriate even without deliberate decision making, (b) are rigid in their execution, and (c) impose low levels of cognitive load. Automaticity can require thousands of training trials.

   Complex skill sets applied in varied situations exhibit a different type of long-term outcome commonly referred to as *expertise*. This is the outcome sought in professional training and other practice scenarios. Expertise is characterized by fast but flexible decision making and superior memory for area-related information. Experts engage in *deliberate practice*, i.e., they intentionally vary already mastered performances to explore possibilities for improvement. The amount of practice required to achieve top-level performance is approximately 10 years, if the learner practices 4 h a day, 6 days a week. These numbers are relatively stable across such otherwise different areas as athletics, the arts, the military, music, and the professions.

Related Topics

The study of *perceptual learning* is not well integrated with other areas of skill research. Some research in the field of *cognitive development* pertains to skill acquisition in children. The study of *social skills* is typically conducted from a different point of view than information processing. The mathematical modeling of learning curves (a.k.a. "learning by doing") is a topic of research in business management and microeconomics, because the negatively accelerated shape of the learning curve has implications for cost calculations for new business ventures. The latter type of research is not well integrated with skill acquisition research in psychology.

Cross-References

► Cognitive Models of Learning
► Computational Models of Human Learning
► Deliberate Practice
► Effects of Instruction and Modeling on Skill Learning
► Expertise
► Feedback in Instructional Contexts
► Imitation Learning from Demonstration
► Procedural Learning
► Subgoal Learning

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Cognitive State

► Belief Formation

Cognitive Strategies

► Learning Strategies

Cognitive Structure

Cognitive structure is a psychological construct that accounts for a form of human knowledge. Schema and mental models are examples of cognitive structures. Cognitive structure provides meaning and organization to experiences and guides both the processing of new information and the retrieval of stored information.

Theorized components of memory for representing, storing, organizing, and retrieving knowledge.

Cross-References

► Mental Models and Lifelong Learning

Cognitive Styles

► Adaptation to Learning Styles
► Jungian Learning Styles

Cognitive Systems

► Cognitive Robotics

Cognitive Tasks and Learning

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Synonyms

Complex tasks; Higher-order tasks; Intellectual tasks; Problem-solving tasks

Definition

Cognitive tasks are those undertakings that require a person to mentally process new information (i.e., acquire and organize knowledge/learn) and allow them to recall, retrieve that information from memory and to use that information at a later time in the same or similar situation (i.e., transfer).

Theoretical Background

Cognitivism

The roots of cognitive psychology and the role of cognitive tasks lie with David Ausubel's *Psychology of Meaningful Verbal Learning* (Ausubel 1963) and Robert Gagné's *Conditions of Learning* (Gagné 1977). According to Gagné, cognitive tasks aim at the acquisition of *intellectual skills* and consist of eight hierarchically organized cognitive processes: stimulus recognition, response generation, procedure following, use of terminology, discriminations, concept formation, rule application, and problem-solving. Gagné identified five major categories of learning (verbal information, intellectual skills, cognitive strategies, motor skills, and attitudes), each requiring different internal and external conditions for it to occur.

Cognitivism was a response to behaviorism which saw learning as a simple response to environmental stimuli. Ausubel, in response to behaviorism, believed that understanding concepts, principles, and ideas is achieved through *deductive reasoning* requiring active participation in of a learner whose actions are a consequence of *thinking*. He called this meaningful learning; as opposed to rote memorization.

Schema Theory of Learning

That which is meaningfully learned is organized in schemata. The *schema theory of learning* (Anderson 1977) views organized knowledge as an elaborate network of abstract mental structures which represent how one understands the world. Schemata (1) are constructed by the learner, (2) are meaningfully organized, (3) are added to and refined as an individual gains experience (Piaget: *assimilation*), (4) are reorganized when incoming data make this necessary (Piaget: *accomodation*), and (5) are embedded in other schemata and contain sub-schemata. In other words, learning can be seen as change in a learner's schemata.

Cognitive Tasks

To mentally process new information effectively, retrieve it from memory, and then use it in the same or similar situations – in other words to perform well on cognitive tasks – one must first *possess* the necessary individual cognitive skills for schema acquisition/schema construction. Then, one must be able to *coordinate* the separate skills that constitute the task. In addition, these skills must be *integrated* with prior knowledge and existing attitudes. Finally, successful performance of cognitive tasks requires *differentiation* by recognizing qualitative differences among the task characteristics that influence the constituent skills that have to be applied.

Cognitive Tasks and Learning

Performing cognitive tasks taxes the learner's limited working memory (cf. Sweller 1988). In other words, it induces significant *cognitive load*. Because of this, effective learning can only commence if the specific instructions within a cognitive task are properly aligned with cognitive architecture (Van Merriënboer and Kirschner 2007). In their *Ten Steps to Complex Learning* Van Merriënboer and Kirschner outline an instructional design model based upon a whole-task approach and provide strategies to align instruction to human cognitive architecture and help people learn how to perform the complex cognitive tasks.

Part-task models of skill acquisition dominated the field of instructional design until the late 1980s. In that approach, one aspect of a skill was learned and practiced until mastery, at which time a new – often related aspect of the skill – was then learnt and mastered, etc., until the "whole" skill was considered to be mastered. Van Merriënboer and Kirschner (2007) stress the use of a *whole-task model of learning* since part-task models have three major shortcomings, namely, they lead to *compartmentalization* (i.e., teaching knowledge, skills, and attitudes separately, thus hindering complex learning and competence development), *fragmentation* (i.e., analyzing a complex learning domain in small pieces corresponding with specific learning objectives, and then teaching it piece-by-piece without paying attention to the relationships between pieces), and *limit transfer* (i.e., transfer paradox: using instructional methods that are highly efficient to reach specific learning objectives, but that are not suitable to reach transfer of learning.). Due to this, there has been a growing interest in whole-task models of learning and instructional design. In dealing with the learning of cognitive tasks, whole-task models provide an alternative to part-task models. Whole-task models, in contrast, analyze tasks as a coherent, interconnected whole and then teach them from very simple, yet meaningful wholes that are representative for the whole task to increasingly more complex wholes, fostering coordination, integration, and transfer of learning.

Whole meaningful tasks, thus, are seen as the driving force for learning. Easy-to-difficult sequencing techniques and learner support and guidance, which may be faded as learners acquire more expertise (i.e., scaffolding), are studied as methods to deal with task complexity. Second, there is a focus on the development of the whole person (i.e., learner-centered) rather than the acquisition of isolated pieces of knowledge, and the learner is co-responsible for a process of competency development. Third, there is a renewed interest in the study of instructional methods that explicitly aim at transfer of learning. Methods that work the best for reaching isolated, specific objectives are often not the methods that work best for reaching integrated objectives and increasing transfer of learning (Van Merriënboer et al. 2006). A whole-task approach takes this paradox into account and is always directed toward reaching multiple, integrated objectives that go beyond a limited list of highly specific objectives. Therefore, whole-task approaches are characterized by the use of mathemagenic instructional methods that give rise to meaningful learning and transfer.

What This Means

Van Merriënboer and Kirschner (2007) present a series of cognitive task types which are well suited to the learner's cognitive architecture and which are also aimed at carrying out and learning from whole tasks. Different types of cognitive learning tasks can be constructed by manipulating the information given to the learner, the goal state to be achieved by the learner, and/or the solution that the learner is required to come up with. Here, for the field of problems in the natural sciences for example, explanations and examples of the different types are presented:

In a *case-study*, learners receive a media claim, relevant articles, and/or information (i.e., facts, theories, etc.), and a way of reasoning which a scientist uses to support or refute the claim. They must evaluate the quality of the argumentation and the information used.

A *reverse task* presents a goal state and an acceptable solution, but the learners have to trace the implications for different claims (i.e., predict the given). In the context of troubleshooting, for example, learners might be told that a particular component is faulted or has failed and predict the behavior of the system based on this (i.e., what they should observe in order to reach a correct diagnosis themselves). Like case studies, reverse tasks focus learners' attention on useful solutions and require them to relate solution steps to given situations.

An *imitation task* presents a conventional task in combination with a case study of an analogous task. The solution presented in the case study provides a blueprint for approaching the new task, focusing attention on possibly useful solution steps. Imitation tasks are quite authentic, because experts often rely on their knowledge of specific cases to guide their problem-solving behavior on new problems – a process known in the field of cognitive science as case-based reasoning.

A *nonspecific goal task* stimulates the exploration of relationships between solutions and the goals that can be reached by those solutions. It invites learners to move forward from the givens and to explore the problem space, which helps them construct cognitive schemas. This is in contrast to traditional, goal-specific problems that force learners to work backward from the goal. For novice learners, working backward is a cumbersome process that may hinder schema construction (Sweller 1988).

A *completion task* provides a given state, criteria for an acceptable goal state, and a partial solution. Learners must complete the partial solution by determining and adding the missing steps, either at the end of the solution or at one or more places in the middle of the solution. A particularly strong point of such tasks is that learners must carefully study the partial solution provided to them, because they will otherwise not be able to come up with the complete solution. Well-designed completion tasks ensure that learners can understand the partial solution and still have to perform a nontrivial completion.

The common element of all of the learning tasks is that they direct the learners' attention to problem states, acceptable solutions, and useful solution steps helping them to mindfully abstract information from good solutions or use inductive processes to construct cognitive schemas that reflect generalized solutions for particular types of tasks.

Important Scientific Research and Open Questions

Cognitive Load

Much research effort has been invested in finding methods to decrease irrelevant cognitive load (i.e., extraneous cognitive load) caused by poor instruction to help learners deal with the complexity of cognitive tasks (Van Merriënboer et al. 2006). Nowadays research in this area is directed to finding means to combine mathemagenic (literally activities or methods of instruction that give birth to learning), whole-task instructional methods with complex cognitive tasks without causing cognitive overload. These activities should/would, on the one hand, lead to a reduction of extraneous load and, on the other, lead to germane cognitive load which is beneficial for learning. However, this combination has only been empirically confirmed for a limited number of concrete instructional methods. More research is needed to show that the combination holds across a wide variety of methods.

Learner Expertise

Probably the most important point to consider when designing education or training programs using cognitive tasks is that the experienced complexity of a task depends on the expertise of the learner. The greater the learner's expertise, the lower the experienced complexity. In a flexible and adaptive learning environment, it should be possible to take differences between individual learners into account when learning tasks are designed and selected. As a consequence, a high-ability student will receive different cognitive tasks, may proceed much more quickly from simple to complex tasks than a low-ability student, and also will need fewer learning tasks to complete the program and achieve the required competency. More research is needed to determine which parameters should be used to most effectively adapt instruction to a learner's needs.

Cross-References

- ► Cognitive Learning
- ► Cognitive Skill Acquisition
- ► Human Cognitive Architecture
- ► Learning Task(s)
- ► Schema Development
- ► Task Sequencing and Learning

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Cognitive Underpinnings of Primate Communication

► Cognitive Aspects of Natural Communication in Primates

Cognitive, Motivation, and Emotional Impairment

► Learned Helplessness

Cognitive-Behavior Therapy with Couples

► Cognitive-Behavioral Family Therapy

Cognitive-Behavioral Family Therapy

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Synonyms

Behavior family therapy; Cognitive restructuring; Cognitive-behavior therapy with couples; Schema therapy

Definition

Cognitive-behavioral family therapy is an approach to family therapy that focuses on the use of principles of behavioral modification (namely, contingency contracting and negotiation strategies) and is designed to change the interactional patterns of family members, as well as the restructuring of distorted beliefs and perceptions that develop as a result of faulty interaction. There is also a heavy emphasis on schema, or what is otherwise known as *core beliefs* in an attempt to evaluate how these impinge on the emotions and behaviors of family members' interaction.

Theoretical Background

Cognitive-behavioral family therapy is based on the tenet that members of the family are simultaneously and/or influenced by each other's actions. Consequently, the behavior of one family member leads to behaviors, cognitions, and emotions in other members, which, in turn, elicits cognitions, behaviors, and emotions in response to the former member. As this cycle continues, the volatility of family dynamics escalates, rendering family members vulnerable to a negative spiral conflict. As the number of family members involved increases, so does the complexity of the dynamics, adding more fuel to the escalation process.

The cognitive portion of the model places a heavy emphasis on schema, or what has otherwise been defined as *core beliefs*. This is also based on the work of Aaron T. Beck et al. (1976), who addressed the issue of automatic thoughts and underlying beliefs and how these are influenced by cognitive distortions. Cognitive distortions are otherwise known as *information processing errors* that contribute to cognitions that can lead to conflict in family members' lives. The content of family members' perceptions and inferences are shaped by relatively stable underlying schemas or cognitive structures. Many schemas about relationships and the nature of family interactions are learned early in life from primary sources such as family of origin, cultural traditions and mores, the mass media, early dating experiences, and other relationship experiences. As a result of years of interaction among family members, individuals often develop jointly held beliefs that constitute a family schema to the extent that the family engages in cognitive distortions that may result in dysfunctional interaction patterns.

The behavioral component of the cognitive-behavioral therapy model addresses observable behaviors and the factors in family relationships that influence it. These techniques include communications training, problem-solving strategies, and behavioral exchange agreements. Much of these techniques are based on the social exchange theory, which centers on the costs and benefits associated with relationships. This theory is based on economic theory and views family interactions through the lens of an exchange of costs and rewards and what behaviors will increase positive exchange as opposed to those that inhibit positive exchange or facilitate negative exchanges. Other aspects of behavioral intervention include assertiveness training, paradoxical techniques and interventions, behavioral rehearsal, and the use of homework assignments.

Included in this theory is the emphasis on affect and emotional regulation in which the concept of schema has been expanded to include multilevel aspects containing details of emotion, physiology, and behavior. Affect of responses from family members are a core component of the cognitive-behavioral approach. The theory behind cognitive-behavior therapy supports the idea that cognitions heavily influence emotion, physiological reactions, and behaviors, and that a reciprocal process exists among those domains. Cognitive-behavior family therapy is concerned with the complex and interdisciplinary relationships among thoughts, feelings, behaviors, and biophysiology of family members. It has chosen a specific method with which to address these components in the pursuit of helping couple and family members change. The processing of emotion is viewed as crucial for survival and is as highly influential to cognitive schemas in the processing of information.

The combination of the cognitive-behavioral approach with families is equally effective with the behavioral conditions, although cognitively focused interventions tend to produce more cognitive change, while behavioral interventions modify behavioral interactions.

Important Scientific Research and Open Questions

Cognitive-behavior therapy has been subjected to more controlled outcome studies than any other therapeutic modality in existence (Dattilio 2001). There is substantial empirical evidence from treatment outcome studies, using cognitive-behavior therapy to indicate the effectiveness with relationships, although most studies have primarily focused on the behavioral interventions of communication training, problem-solving training, and behavior contracts, with only a handful of studies examining the impact of cognitive restructuring procedures (see Baucom et al. 1998, for a review that employs stringent criteria for efficacy). Baucom et al. (1998) review of outcome studies indicate that cognitive-behavior therapy is efficacious in reducing relationship distress. Cognitive-behavioral approaches gained popularity and respect among clinicians, including couple and family therapists (Bitter 2009; Dattilio 1998a; Dattilio and Epstein 2003; Epstein and Baucom 2002; Davis and Piercy 2007; Nichols and Schwartz 2008).

Epstein (2001) has produced an excellent overview of the empirical status of cognitive-behavior therapy with relationships. More recently, Dattilio and Epstein (2003) and Dattilio (1998a) published an overview of both couples and family therapy with additional emphasis on family schema. A more comprehensive text by Dattilio (2010) outlines all of the research literature up to date. Sadly, the area of cognitive-behavior therapy with couples has substantially more quantitative studies than that of family therapy (Baucom et al. 1998; Dattilio and Epstein 2003; Epstein 2001; Dattilio 2010). The most recent of the family therapy studies include the treatment of schizophrenia in the early 1980s, as well as those studies conducted by Barrowclough and Tarrier (1992).

An open question remains the need for future research with family cognitive-behavioral family therapy. An emphasis needs to focus on examining the application with different types of family problems and also cultural variations (Dattilio 1998b). It would also be interesting to examine the various characteristics of family members and determine what constitutes differential responses to treatment, as well as optimal sequences of behavior and the restructuring of schemas. Comparative studies, if conducted, would help to isolate the specific characteristics that render cognitive-behavior family therapy effective and also discover which components are most advantageous for integrative purposes with other modalities.

Cross-References

- ► Application of Family Therapy on Complex Social Issues
- ► Behavior Modification, Behavior Therapy, Applied Behavior Analysis and Learning
- ► Behavior Therapy

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Cognitive-Behavioral Therapy

► A Tripartite Learning Conceptualization of Psychotherapy

Cognitive-Code Approach

► Cognitive-Code Learning

Cognitive-Code Learning

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Synonyms

Code-cognition approach; Cognitive-code approach; Cognitive-code learning theory

Definition

Cognitive-code learning refers to a theory of second language teaching and learning rooted in cognitivist psychology and structural applied linguistics developed in the 1960s. The theory emphasizes the central role of cognition in the conscious and explicit learning of the rules of a language as a code. The cognitive-code approach to learning a second language sees it as a study of language as a complex system with the goal of gaining conscious control of the grammatical, lexical (vocabulary), and auditory patterns.

Theoretical Background

Cognitive-code learning theory was proposed and widely debated in the 1960s. Based on the foundations of linguistic theories and the findings of psycholinguistic research, cognitive psychologists and applied linguists, such as John B. Carroll and Kenneth Chastain, advocated the cognitive-code approach to the study of a second language as an alternative to the audio-lingual method prevalent at the time. Cognitive-code learning theory (Chastain 1971) proposes that learning a second language requires explicit instruction and a study of the language as a complex and rule-governed system (Carroll 1964). This approach took the view of a conscious study of the language structure as central and placed a great deal less emphasis on the development of a second language as a combination of skills. In the current perspective on second language learning, cognitive-code theory is largely seen as an updated variety of the traditional grammar-translation method, with an attendant goal of overcoming the shortfalls of the audio-lingual approach. At its core, cognitive-code learning represents a theoretical, rather than a pedagogical approach. In part due to the fact that this theoretical proposal met with debate and skepticism, its tangible outcomes in the form of curricula, methods, or teaching techniques did not materialize.

Providing learners opportunities for a great deal of meaningful practice in a second language constitutes the central precept of the cognitive-code approach. The main emphasis on meaningful practice underscored the need for the learner first to understand the language rules and then apply them in the context of practical language use. Thus, the explicit study of language rules, such as in grammar and vocabulary, was not only expected, but strongly encouraged. In the context of structural linguistics and behavioral psychology, cognitive-code learning envisions practice to be meaningful when learners clearly understand and are able to apply language rules in practice. The essential difference between the audio-lingual approach and the cognitive-code approach is that in the former, structural learning without an explanation and pattern drills are seen as leading to modifications in the learners' language behavior, while in the latter, students need to understand the linguistic rules before these can be implemented in practice. According to Carroll (1966, p. 102), "the theory attaches more importance to the learner's understanding of the structure of the foreign language than to the facility in using that structure, since it is believed that provided the student has a proper degree of cognitive control over the structures of the language, facility will develop automatically with use of the language in meaningful situations."

Important Scientific Research and Open Questions

To a great extent, cognitive-code learning theory was based on contemporary developments in transformational grammar and the generative theory of language that saw its heyday in the 1950s and 1960s. In this light, the cognitive-code approach did not have much appeal to language teachers whose training rarely entailed a detailed familiarity with grammar rules and abstract concepts of syntax. By the mid-1970s, the cognitive-code approach had all but disappeared among other competing theories of second language learning, and more specifically, due to the prominent rise of communicative language teaching. The influence of cognitive-code learning on the subsequent methodological developments in second language teaching was felt in the evolution of error analysis and the need for contextualized grammar instruction. More specifically, in language pedagogy, the cognitive-code proposal has lead to a realization that linguistic structural rules, as, say, in grammar teaching, are not syntactic abstractions but are an integral component of language production and use in writing or interaction. It is important to note, however, that by the mid to late 1970s, the impact of cognitive and general linguistic theories on teaching was greatly diminished and supplanted by sociocultural and interactional views of language learning and teaching.

Cross-References

► Cognitive Learning
► Cognitive Skill Acquisition
► Grammar Learning
► Second Language Learning

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Cognitive-Code Learning Theory

► Cognitive-Code Learning

Cognitive-Economy Assumptions for Learning

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Synonyms

Representational assumptions

Definition

► Cognitive economy refers to the combined simplicity and relevance of a categorization scheme or knowledge representation.

► Representational assumptions are the built-in biases of a representation that give sensitivity to certain features of the world instead of others.

► Cognitive-economy assumptions for learning are those representational assumptions that allow a cognitive agent to focus on details that matter, while avoiding the distraction of irrelevant features.

Theoretical Background

Cognitive agents categorize their perceptions in order to avoid overwhelming their bounded cognitive resources with the vast sea of stimuli presented to their senses. The goal is to "provide maximum information with the least cognitive effort," "conserving finite resources as much as possible" (Rosch 1978, p. 28). This common sense idea has informed our understanding of human perception, learning, and reasoning.

Human perception appears to be categorized according to cognitive-economy assumptions that cause us to see "a qualitative difference in how similar things look or sound depending on whether or not they are in the same category" (Harnad 1987, p. 2). This phenomenon is termed *categorical perception*. It appears to be biologically constrained, at least in part. For example, even though color stimuli vary along a smooth continuum of wavelengths, humans break that continuum into a small set of labeled regions. According to Berlin and Kay (1969), humans break the color spectrum into 11 basic color categories, although cultures differ in whether they have basic color terms for all 11. We judge color differences as smaller if they come from the same category, and larger if they come from different categories, even when the wavelength difference is the same. The same effect characterizes perception of speech sounds such as the stop-consonant categories /ba/, /da/, and /ga/ (Harnad 1987, p. 2).

Other evidence indicates that perceptual categories are the result of experience and learning. For example, infants that grow up in a particular language environment, say, English, appear to lose the ability to discriminate speech sounds absent from that environment during the first year of life (Werker and Tees 1984). These changes suggest that human perception develops category distinctions that give us a functional advantage for interactions with our environment.

Human reasoning and problem solving also appear to benefit from our innate cognitive-economy assumptions. Herbert Simon (1957) used the term *bounded rationality* to describe our limited cognitive capacity – much too small to produce objectively rational behavior in the real world. Therefore, we construct a simplified model of reality that allows us to discard details that appear tangential to our task.

Simon's analysis has been born out in studies of experts and novices. Experts appear to represent the relevant details of their tasks much more efficiently than novices. The experts have learned "what to look for," and have learned to disregard spurious features. For example, experiments with chess players have shown that a key difference between master players and lesser players is that the masters are able to immediately recognize the important attributes of a chess position (de Groot 1965). But this ability only extends to chess positions from actual games. When presented with random chess boards, the experts had no advantage.

Important Scientific Research and Open Questions

Cognitive economy is based on the common sense idea expressed so aptly by Albert Einstein: "Make everything as simple as possible, but not simpler." Irrelevant details distract, but some features prove critical. We are beginning to develop an understanding of these issues in terms of generalization, sample complexity, and computational learning theory, but many questions remain, such as these: How can we measure the importance of features? When does the discriminating power of a new feature justify the added expense of increasing complexity? What are the best ways to recognize the important features as we learn a task from scratch? How do our categorical assumptions change our view of the world – and what is their effect on learning? It is difficult to answer these questions in the general sense because relevance and value depend upon the task at hand, the agent, and the relative costs of computation time, mistakes, and risk.

Choosing an appropriate representation often is the most critical step of solving a problem – as will be apparent to anyone who has tried to multiply numbers represented as Roman numerals. Cognitive economy assumptions affect every field involving decision-making or skilled performance. Examples include the following.

Writing: Effective technical writing provides the reader with an appropriate level of detail. Too much detail will confuse the reader.

Teaching: Students need to develop effective representational constructs for the topic at hand, and the teacher must communicate concepts in terms the students can understand.

Athletic performance: Keep your eye on the ball! Learn how to recognize an opponent's intentions and pending actions.

Design: Objects may present *perceived affordances* that enable the user to recognize how the object may be used. For example, some doors have a brass push plate on one side and a pull handle on the opposite side, making usage obvious. Design of human–machine interfaces (e.g., computer technology) can either make human use error-prone and frustrating (and thus expensive), or intuitive and empowering. In automobiles and in airplane cockpits, cognitive economy assumptions may have life-and-death consequences.

Machine learning: Feature extraction and feature selection are both areas of active research at major conferences such as AAAI (the annual conference of the Association for the Advancement of Artificial Intelligence) and ICML (the International Conference on Machine Learning). In order for researchers to analyze data with computers, they must first design an appropriate representation for that data. Thus, cognitive economy assumptions critically affect the success of scientific work in medicine, astronomy, geography, physics, and social science.

Cross-References

► Affordances
► Categorical Representation
► Cognitive Efficiency
► Expertise
► Judgment of Similarity
► Knowledge Organization
► Knowledge Representation
► Mathematical Models Theories of Learning
► Mental Representation
► Role of Prior Knowledge in Learning Processes

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Cognitivism

A theory of learning which considers that learning can be compared to the way a computer processes information. The learner gathers information and constructs an internal symbolic database of real world objects and experiences. Information may come from a perceived expert (the teacher). Learning focuses on structured schemas.

Coherence Effect

► Redundancy Effect

Co-learning

► Learning by Eliminating

Collaboration

From Latin *com-* + *laborare* to work jointly with others or together especially in an intellectual endeavor. A synergic relationship among participants sharing their knowledge or skills, engaged in a specific context using implicit or explicit interaction rules to achieve one or more valuable and situated outcomes.

Cross-References

► Learning Through Social Media

Collaboration Scripts

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Synonyms

Cooperation scripts; Instructional support; Scaffolding; Scripted cooperation

Definition

Collaboration scripts are a specific type of scaffolds for collaborative learning that is characterized by its focus on supporting learning through direct manipulation of collaboration processes rather than through offering content-specific support. A *collaboration script* is a set of instructions which aims to guide and support two or more learners to interact and behave during collaborative learning in a way that all learning partners benefit from collaboration. The aim of the collaboration script is to enhance learning of group members by engaging them in cognitive (e.g., explaining, questioning, summarizing), metacognitive (e.g., monitoring, regulating, formulating arguments), and social activities (e.g., taking turns, listening, playing specific roles, etc.) related to individual knowledge and skill acquisition. Collaboration scripts specify, sequence, and distribute these activities among the learning partners of a group and often attach them to specific collaboration roles. Thereby, they can vary with respect to how much structure they provide: so-called macro-scripts bring specific collaboration phases in a certain order, but do not give further instructions on how learners should act in these phases. So-called micro-scripts, in contrast, offer more specific instructions on how to perform certain activities, for example, by prompting one learner to give a constructive critique on a learning partner's contribution (e.g., "What I did not understand in your contribution was. . .").

Theoretical Background

There is plenty of evidence both in face-to-face and ► computer-supported collaborative learning (CSCL) situations showing that unstructured collaboration usually does not lead to high achievements with respect to learning. Therefore, different approaches for instructing learners' collaborative activities, called collaboration scripts, have been created both for face-to-face and CSCL situations (Fischer et al. 2007). Research on collaboration scripts includes a vast variety of different script variants. Despite this diversity, five central conceptual components of collaboration scripts can be identified, which are the following (Kollar et al. 2006): First, collaboration scripts are directed towards specific *learning objectives*, such as the acquisition of domain-specific knowledge or domain-general competences. Second, they try to engage learners in particular *activities* that are functional with respect to reaching these objectives (e.g., explaining, argumentation, questioning). Third, these activities are typically to be shown in a particular *sequence* (e.g., first reading a text, then summarizing it, then making predictions). Fourth, activities are often clustered to *roles* that are distributed (e.g., an explainer and a listener) and may be switched among the learning partners. Finally, scripts can vary with respect to their *type of representation*, that is, they may be presented to the learners as oral instructions, but also as instructional texts or they may be embedded in the communication interface in a CSCL environment.

Two prototypical realizations of the collaboration script approach are "Scripted Cooperation" (O'Donnell 1999) and "ArgueGraph" (Dillenbourg and Jermann 2007). The Scripted Cooperation approach supports groups of two learners in learning from text. The text is split up into paragraphs by the learners or the teacher before learners read the first passage individually. After that, learners put the text aside and one learner has the role of the recaller, whose aim is to recall the text information as completely as possible. Simultaneously, the learning partner is in the role of the listener, who tries to catch misconceptions and identify omissions. After this, learners jointly elaborate the text content to make it more memorable. Then the next passage of the text is read and the procedure of the activities is repeated as in the first round except that learners switch their roles. The learning objectives for the learners are acquiring the domain-specific content knowledge and domain-general text-learning strategies. In order to reach these goals, learners engage in cognitive activities, such as explaining, and metacognitive activities, such as monitoring. Activities are sequenced in a fixed order, according to which learners need to read a text, then to summarize it and identify misconceptions and omissions, and jointly elaborate the text content. Learners are assigned to play roles, such as the recaller and the listener, and these roles are switched several times during the learning process. The script instructions are usually presented by the teacher and practiced prior to collaboration.

Unlike Scripted Cooperation, which offers instructional support for collaborative processes occurring within dyads of learners, ArgueGraph aims to integrate small group, individual, and whole-class activities in the computer-supported classroom situation. First, learners are asked individually to fill in a computer-based multiple-choice questionnaire (e.g., on the topic "Theoretically driven courseware design") and give an argument for each choice in an open text window. Once each student has completed the questionnaire, the software system creates a graph which shows learners' positions on different predefined dimensions (e.g., permissiveness) compared to other learners based on their answers. Second, the graph is looked through and discussed with the whole class in the plenary session. After this, the system automatically builds pairs by selecting the learners who have the most contrasting positions in the graph to work together. Third, the dyads' task is to answer the same questionnaire together, select one answer per question, and finally give a joint argument for their selection. During that process, significant argumentation activities are expected to happen. After this phase has been completed, the system shows a new graph based on the answers of individuals and pairs as well as an aggregation of the arguments. Fourth, there is a plenary phase in which the teacher discusses with the learners about their arguments, asking explanations, organizing their arguments into theories, clarifying definitions, etc. Finally, each learner writes a synthesis of arguments from a specific question. Learning objectives are to acquire domain-specific knowledge (e.g., courseware design and learning theories) and domain-general competences (e.g., argumentation). Activities students engage in are, for example, elaborating, explaining, and formulating arguments and counterarguments. The activities are sequenced both with respect to their type and the social level (individual, small group, plenary) on which they are supposed to occur. For example, in pairs, learners are not only asked to formulate arguments, but also counterarguments, when trying to reach a joint position with their fellow learners. Learners are not explicitly assigned to the roles, but they are, for example, taking the roles of the opponent, the defender, or the explainer. Switching roles takes place when learners are engaging in different activities. The script's representation is located in both the teacher's instruction and the particular design of the computer-based learning environment which provides instruction on what is supposed to happen during the particular learning phase.

Scripted Cooperation and ArgueGraph represent a considerable amount of diversity that also becomes apparent when more collaboration scripts are considered in the literature. As ArgueGraph focuses on an orchestration of learning processes within a complex social system by integrating individual, small group, and whole-class activities, it is a proponent of more macro-level scripting which leaves learners considerable freedom to interact in a way they want and play different roles. Scripted Cooperation, in contrast, aims to support small group activities in a more fine-grained manner and requires both learners to engage in particular predefined activities and play two roles during collaboration. Therefore, Scripted Cooperation represents more micro-level scripting. However, activities and roles may be even more prestructured by using prompts or sentence starters (e.g., "What does.... mean?," "Tell me more about..."), which has been realized especially in purely computer-based collaboration scripts that can be found in the literature (e.g., Weinberger et al. 2005).

Important Scientific Research and Open Questions

The research conducted with collaboration scripts shows positive effects with respect to domain-specific knowledge and domain-general competence. However, there are variations in learners' outcomes. Even highly coercive collaboration scripts cannot be expected to completely determine the success of collaborative learning. Rather, the students also bring "internal" collaboration scripts with them which guide their behavior during collaboration. These "internal" collaboration scripts have been acquired through repeated experience in collaborative situations and are highly resistant to change (Schank 1999). Therefore, learning can be interrupted if learners' internal scripts are inconsistent with a given external script or if the external script overestimates learners' skills and ability. Fading might be a solution for reconciling external and internal scripts in an adaptive way in order to avoid over- and under-scripting problems. This approach means that less and more support can be provided during activities depending on an individual learner's or group's needs. In order to increase or decrease support in the right moment means that the group processes need to be observed in real time. Yet, monitoring multiple groups on a more detailed level at the same time is an impossible task for one teacher in a classroom, but could be done by technology. First computer-supported analysis software tools are within reach that are able to assess collaboration processes in real time and use these analyses for fading external scripts in and out when appropriate.

Cross-References

- ▶ Cognitive and Affective Learning Strategies
- ▶ Collaborative Learning
- ▶ Computer-Supported Collaborative Learning
- ▶ Cooperative Learning
- ▶ Group Learning
- ▶ Metacognition and Learning
- ▶ Small-Group Learning
- ▶ Team Learning

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Collaborative e-Learning

▶ Collaborative Learning Supported by Digital Media

Collaborative Knowledge Creation

▶ Knowledge Creation Metaphor, The

Collaborative Learning

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Synonyms

Cooperative learning; Small group learning; Team learning

Definition

Collaborative learning is a process by which students interact in dyads or small groups of no more than six members with intent to solicit and respect the abilities and contributions of individual members. Typically, authority and responsibility are shared for group actions and outcomes. *Interdependence* among group members is promoted and engineered. Collaborative learning changes the dynamics of the classroom by requiring discussion among learners. Students are encouraged to question the curriculum and attempt to create personal meaning before the teacher interprets what is important to learn. Opportunities to organize, clarify, elaborate, or practice information are engineered, and listening, disagreeing, and expressing ideas are as important as the "right answers." In classrooms that support this type of ideology, the student is an active participant in learning rather than a passive recipient of education from an expert source. Collaborative learning is an overarching term referring to a set of small group educational approaches that share these common characteristics. Various names given to forms of collaborative learning include reciprocal learning, team learning, study groups or circles, peer teaching, and the most well-known, cooperative learning.

Formal learning groups, informal learning groups, and study teams are the most common formats for collaborative learning. *Formal learning groups* are arranged to complete an explicit project or task that may take place in a single class period or over a number of weeks in a unit or semester of instruction. There is sustained collaboration to accomplish the academic assignment. *Informal learning groups* are temporary groupings of students that can be formed spontaneously in the context of a class session. Checking for understanding, solving a problem, responding to a question, comparing ideas or notes are typical uses for informal groups. *Study teams* are formed for the specific purpose of providing mutual support to complete course or class assignments. Membership is consistent and maintained across over the time period of the course. Time for study teams to work together can be arranged in the context of the class but often in secondary and higher education settings members meet regularly outside of class to study together and provide assistance or feedback to one another.

Theoretical Background

Collaborative learning as a philosophy and technique of interaction is rooted in constructivist and social learning theories as well as the pedagogy of social justice (Bandura 1977; Freire 1970; Vygotsky 1978). Vygotsky (1978), in his theory of *social constructivism* posited that the nature of learning is inherently collaborative and it is impossible to separate learning from its social context. Social discourse is the means by which cognitive functions and knowledge are developed. A critical tenet of this theory is that knowledge or the way humans understand their experiences and reality is not simply constructed, it is co-constructed through the frameworks of language and culture in relationships among individuals. Through the lens of social constructivism collaborative learning establishes the community in which knowledge can be cocreated, provides opportunities for individuals to learn from more competent peers, and promotes conceptual development through the experiences of modeling, perspective taking, and cognitive challenges.

Social learning theory (Bandura 1977) suggests that human behavior is influenced by the interaction among cognitive, behavioral, and environmental factors. The reciprocal social interaction is yet again critical as it provides a context in which individuals cannot only observe, but model the attitudes, reactions, and behavior of others. Only through observing others does the individual develop behavioral and intellectual repertoires and have a guide for how these new skills are performed. Accordingly, in collaborative learning the individual has ample opportunities to be exposed to other conceptual constructs while being able to rehearse their understanding of new behavior.

Morton Deutch in 1949 formally conceptualized *social interdependence theory.* The primary principle guiding the theory is that the way goals are structured determines how individuals interact, which in turn creates outcomes (Johnson and Johnson 2005). Social interdependence exists when the outcomes of individuals are affected by the actions of others. There are two types of interdependence, positive and negative. *Positive interdependence* exists when actions of individuals promote the achievement of joint goals, resulting in *promotive interaction.* Alternatively when actions impede the achievement of other's goals, oppositional interaction occurs. Collaborative learning is structured to facilitate positive interdependence. Promotive or positive interactions take place when an individual makes a choice to engage in actions that help others achieve their goal or a joint outcome. Negative interdependence occurs when an individual or multiple members of a team engage in actions that are counterproductive to the entire group reaching its goals. Collaboration or cooperation doesn't exist until promotive actions are taking place. If structured well, collaborative learning can be the arena where individuals move from self interest to making the group's interest central.

Paulo Freire (1970) helped establish the discourse of *social justice* that would guide more democratic and humanistic orientations to the process of learning. Unfortunately in classrooms across the world students are still asked to sit in desks for long periods of time and be passive recipients of instruction that is dictated by others. Freire deemed this *banking education* in which unknowing students are passive receptacles of "deposits" made by an instructor who grants the gift of her knowledge. In this traditional paradigm the teacher is the subject of the learning process and the student is the object. Clearly dehumanizing, Freire called for education that was student-centered, relevant, multicultural, democratic, and dynamic. He felt that education should be pursued collaboratively, requiring a dialogue between educator and students. In addition, the process of educational liberation must include both personal effort and external help. Collaborative learning can be a vehicle of empowerment for both students and instructors envisioned by Freire. Students have significant agency in their own learning while being supported in dialogue and problem-solving by a trusted educator.

Important Scientific Research and Open Questions

Research at all levels of schooling has indicated that students learn and retain more when they have agency in the process and have opportunities to speak, listen, share, interact, reflect, and be active. Over 750 studies have focused on the positive aspects of collaborative learning and its underlying learning theory (Johnson and Johnson 2005). Two studies will be highlighted here to illustrate the influence that both simple and more complex forms of collaboration can have on student outcomes in comparison to traditional teaching practices.

In a well-known study Ruhl et al. (1987) examined what happens when students are given opportunities to share understanding of classroom content at key points in a lecture sequence. Two groups of university students received the same instruction in two different ways. In the experimental group, an instructor paused for 2 min on three occasions (intervals between pauses were approximately 15 min) during each of five lectures. During the pauses, while students simply worked in pairs to discuss and rework their notes, no interaction occurred between instructor and students. At the end of each lecture, students were given 3 min to write down everything they could remember from the lesson. Twelve days after the last lecture students were also given a multiple-choice test to measure long term retention. A control group received the same lectures as those in the "pause procedure" group and was similarly tested. In two separate courses repeated over two semesters, the results were consistent. Students who experienced more student-to-student interaction and were more involved in the learning process did significantly better on the daily assessments and on the final multiple-choice test. The magnitude of the difference in mean scores between the two groups was large enough to make a difference of two letter grades. This study suggests that if teachers talk less (even 6 min less as noted in this study) and brief pauses for collaboration are engineered, students can learn more effectively.

In a highly regarded study funded by the *National Science Foundation*, Springer et al. (1999) reviewed hundreds of studies to conduct a metanalysis of the effect of small-group/collaborative instruction on student outcomes in university level science, technology, engineering, and mathematics (STEM) classes. At the time of this study a report by the American Association for the Advancement of Science advised that the work of professionals in the sciences is not done in isolation, but collaboration is necessary at all levels. Current instructional methods that focused on traditional teaching rather than student learning raised concerns that professionals were ill prepared to solve real world problems in cooperative ways. Consequently, frequent group activity in the classroom and experience sharing responsibility for learning was called for at a national level. In the meta-analysis conducted of the 39 highest quality studies, the use of small group learning for undergraduates in STEM classes showed significant and positive effects on ► achievement, persistence in courses, and favorable attitudes toward courses when compared to students who did not work collaboratively. On these three broadly defined outcome measures the effect size for all three variables was about 0.50. Achievement differences which included grades and test scores showed an effect size of 0.51. This difference would move a student from the 50th percentile to the 70th percentile in a course. An effect size of 0.46 was identified in the area of persistence, indicating that by using small group and collaborative learning methods classes and institutions would reduce their attrition by 22%. Student attitudes about their own competence and the subject matter were also positively affected by their exposure to small-group instruction. The effect size on this measure was 0.55 for attitudes in small group settings versus an average effect of 0.28 for other classroom interventions.

Cross-References

- ► Action-Based Learning
- ► Active Learning
- ► Collaborative Learning and Critical Thinking
- ► Collaborative Learning Strategies
- ► Collaborative Learning Supported by Digital Media
- ► Group Cognition and Collaborative Learning
- ► Group Learning
- ► Learning in the Social Context
- ► Multimodal Learning Through Media
- ► Social Construction of Learning
- ► Social Interactions and Learning
- ► Social Learning Theories
- ► Trust into e-Learning

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Collaborative Learning and Critical Thinking

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Synonyms

Cooperative learning; Creative thinking; Problem-solving

Definition

The term “collaborative learning” refers to an instruction method in which students at various performance levels work together in small groups toward a common goal. Collaborative learning is a relationship among learners that fosters positive interdependence, individual accountability, and interpersonal skills. “Critical thinking” involves asking appropriate questions, gathering and creatively sorting through relevant information, relating new information to existing knowledge, reexamining beliefs, reasoning logically, and drawing reliable and trustworthy conclusions.

Theoretical Background

The advent of revolutionary information and communication technologies has effected changes in the organizational infrastructure and altered the characteristics of the workplace putting an increased emphasis on teamwork and processes that require individuals to pool their resources and integrate specializations. The increased pressure to perform tasks with fewer employees, at faster speeds, and with more quality and customer responsiveness creates the need for efficient teamwork. Workers need to be able to think creatively, solve problems, and make decisions as a team. A person who thinks critically can ask appropriate questions, gather and creatively sort through relevant information, relate new information to existing knowledge, reexamine beliefs, reason logically, and come to reliable and trustworthy conclusions. Critical thinking and collaboration are intricately linked to realize gains in productivity. Let us individually examine the constructs of collaboration and critical thinking and next discuss the relationship between them.

The training to work effectively in teams should begin at an early age in school and continued through college. Education has long investigated the effectiveness of collaborative work to enhance student learning. The concept of collaborative learning, the grouping and pairing of students for the purpose of achieving an academic goal has been widely researched and advocated throughout the professional literature. The term “collaborative learning” refers to an instruction method in which students at various performance levels work together in small groups toward a common goal (Gokhale 1995). Collaborative learning is a relationship among learners that fosters positive interdependence, individual accountability, and interpersonal skills. In small groups, students can share strengths and also develop their weaker skills, while learning to deal with conflict.

Group size is very important in collaborative structures. Dyads have many advantages as a functional unit since the likelihood of participation increases when there are only two individuals involved. A potential disadvantage to dyadic interaction may emerge on complex tasks, as there may be insufficient resources to generate appropriate strategies to complete the task. As group size increases, the likelihood of having someone in the group who can satisfactorily complete a challenging task increases. However, the larger the group, the more opportunity there is for diffusion of responsibility among group members or for exclusion of some members. Active participation in the collaborative process is essential for learning to occur. Optimum group size is dependent on the task; for in-class informal activities, group size is often in the range of two to four students while a group of three to five students may be appropriate for a semester-long project (Slavin 1995). Thus, a group size of three to four is optimum and promotes positive interdependence, yet provides sufficient diversity of opinions and backgrounds, which is influenced by group composition.

Much of the literature emphasizes that groups should be heterogeneous when possible; heterogeneity among group members refers to general differences like age, gender, race, ethnicity, and performance in school, or task-specific differences like proficiency in the subject-matter. Studies indicate that some difference of viewpoints is required to trigger interactions but within the boundaries of mutual interest and intelligibility. Studies indicate that grouping learners with even distribution of abilities results in better learning when compared to learning outcomes of randomly mixed groups with varied student abilities. There is no clear way to maximize group diversity and prevent individual isolation. An advantageous compromise is to cluster at least two students of the same kind, say two women or two students of common ethnicity, or two students of same ability, in a group of four (Cooper et al. 1990). A consciously designed group permits a healthy balance of homogeneity and heterogeneity among its members.

For collaborative learning to be effective, the instructor must view teaching as a process of developing and enhancing students' ability to learn. The instructor's role is not to transmit information, but to serve as a facilitator for learning. This involves creating and managing meaningful learning experiences and stimulating students' thinking through real-world problems. Yet, the task must be clearly defined and be guided by specific objectives. There is no reason to expect that unstructured collaboration will result in the expected learning outcomes so this predicament has been tackled by the use of scripts.

Scripts structure collaborative learning by creating roles and mediating interactions while allowing for flexibility in dialog and activities (Kollar et al. 2006). Scripting is a compromise between the constraints usually induced by instructional design and the freedom of collaborative learning. There are two broad types of scripts: macro-scripts and micro-scripts. Macro-scripts aim at creating situations within which desired interactions will occur by describing groups, roles, and phases while micro-scripts emphasize the communication process students must engage in and activities of individual learners. A psychoanalysis of the group discussions reveals useful information. The goal is to enhance the probability that interactions in a group are educational and result in enhancing higher-order thinking skills.

Thinking is often casual and informal but critical thinking calls for persistent effort to apply theoretical constructs to understanding the problem, consider evidence, and evaluate methods or techniques for forming a judgment. The cognitive skills of analysis, interpretation, inference, explanation, evaluation, and of monitoring and correcting one's own reasoning are at the heart of critical thinking (APA 1990). Critical thinking not only mimics the process of scientific investigation – identifying a question, formulating a hypothesis, gathering and analyzing relevant data, using it to test and eventually accepting or rejecting the hypothesis, and finally drawing conclusions – but executes it repeatedly.

Collaborative learning facilitates the expression of the thought processes in a non-stressful environment and provides opportunities to examine and reexamine beliefs and conceptions of the subject-matter in the light of evidence that may or may not support them. When students are confronted with different interpretations of the same situation, the peer support system makes it possible for the learner to internalize new knowledge and convert that into tools for intellectual functioning. The medium provides students with opportunities to analyze, synthesize, and evaluate ideas cooperatively. The informal setting facilitates discussion and interaction. This group interaction helps students to learn from each other's scholarship, skills, and experiences.

When collaboration is structured, group diversity in terms of age, gender, ethnicity, and knowledge and experience contributes positively to the learning process. Students are asked to go beyond mere statements of opinion by giving reasons for their judgments and reflecting upon the criteria employed in making these judgments. Thus, each opinion is subject to careful scrutiny, and the ability to admit that one's initial opinion may have been incorrect or partially flawed is valued.

Proponents of collaborative learning claim that the active exchange of ideas within small groups not only increases interest among the participants but also promotes critical thinking. According to Johnson and Johnson (1989), there is persuasive evidence that cooperative teams achieve at higher levels of thought and retain information longer than students who work quietly as individuals. The shared learning gives students an opportunity to engage in discussion, take responsibility for their own learning, and thus become critical thinkers. Gokhale (1995) found that students who participated in collaborative learning performed significantly better on a critical-thinking test than students who studied individually, while both groups did equally well on a drill-and-practice test. Students are capable of performing at higher intellectual levels when asked to work in collaborative situations than when asked to work individually.

The development and enhancement of critical-thinking skills is one of the primary learning goals in technical disciplines. Educational research investigates effective methodologies for nurturing higher-order thinking skills and preparing students to deal with increasingly complex workplace problems. Researchers report that students working in small groups tend to learn more of what is taught and retain it longer than when the same content is presented in other instructional formats. Additionally, students learn how to communicate effectively, provide leadership, and practice social skills.

Important Scientific Research and Open Questions

The explosion of knowledge and information technology has altered the characteristics of the learning environment; higher education continues to adapt to the digital culture and changes in student learning styles. Today, it is even more imperative that students acquire critical thinking skills to manage information overload. So the question is, how do we investigate the effectiveness of collaborative learning to enhance critical thinking skills in digital environments? How relevant is heterogeneity among group members when avatars are taking the place of real people? How does an instructor provide structure and effectively intervene in asynchronous communications? What is the difference in dynamics of face-to-face and online communications?

The corporate culture is changing too with virtual meetings, remote access, and globally spread-out teams becoming a reality. Critical thinking is part of a lifelong learning process and collaboration fosters its development through discussion, clarification of ideas, and evaluation of others' ideas. Future research studies need to investigate the implications of virtualization for enhancing critical thinking. A psychoanalysis of online group discussions could reveal useful information.

Cross-References

- ▶ Collaborative Learning
- ▶ Collaborative Learning Strategies
- ▶ Cooperative Learning
- ▶ Creative Inquiry
- ▶ Creativity and Learning Resources
- ▶ Critical Learning Incidents

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Collaborative Learning Environment

▶ Online Collaborative Learning

Collaborative Learning Strategies

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Synonyms

Active learning strategies; Cooperative learning strategies; Small group learning strategies; Team learning strategies

Definition

Collaborative learning strategies are explicit approaches or procedures to guide the process of collaborative learning. *Collaborative learning* occurs when dyads or small groups have been engineered to share responsibility, authority, and learning outcomes. Collaborative learning strategies provide the frameworks and step-by-step processes to facilitate interdependence among group members, active participation, interactive dialogue, and cocreation of academic products, all of which are hallmarks of collaborative learning. In essence, these strategies are the architecture or infrastructure to facilitate construction of knowledge among students. Like *active learning strategies* an underlying principle of collaborative learning strategies is meaningful student engagement. Collaborative learning strategies are inherently active; however, not all active learning strategies are collaborative. Whereas many active strategies can be performed independently, collaborative learning strategies support the mutual engagement of participants in synchronous activity while developing a shared conception of a problem or experience (Roschelle and Teasley 1995).

Specific collaborative learning strategies can be enlisted to help groups to organize, clarify, elaborate, or practice information. Based on the intent of the learning experience collaborative learning strategies can be engineered to promote a range of communication and social skills (e.g., acceptance of others, listening, questioning, discussion, conflict resolution, and perspective taking) and cognitive processes (e.g., higher level reasoning, application of knowledge, creative thinking, problem solving, and long-term retention of concepts). A selected strategy sets a course of action for academic and social interactions and provides a plan for students to learn *how* to collaborate in pairs, teams, or as an entire class. These strategies are content-free procedures that can be used across subjects, grade, and age levels with variations in complexity and academic purpose.

Theoretical Background

Collaborative learning strategies share the same theoretical foundations as collaborative learning. Descriptions of social constructivism, social learning theory, social interdependence theory, and social justice pedagogy can be found under the *Collaborative Learning* entry of this publication. A specific collaborative learning strategy will be used here to illustrate how these key theoretical orientations are represented.

Classify, Categorize, and Organize, described by Udvari-Solner and Kluth (2007), is a collaborative learning strategy particularly well suited to teaching and learning new concepts. The approach can be used for small groups or an entire class and is carried out in the following manner:

- The instructor creates note cards, strips of paper, or actual pictures related to concepts that can be classified, categorized, or ordered in two or more groups (e.g., different species of animals, words that are different parts of grammar such as nouns and verbs).
- Each student receives one card that will fit into at least one category or group. Students must actively move around the room viewing every class member's card to find others with related concepts.
- When students believe they have classified themselves correctly, the group is given a short amount of time to identify its category and determine how the different parts of information each person holds are related. Each group is asked to report its newly integrated findings to the class. The group members may also add novel or additional information they know about the concept that is not represented on their cards.
- Only after each group presents does the instructor pose questions, provide information that will reinforce key points, clear up misconceptions, or provide more elaborate explanations.

Three applications of this collaborative learning strategy that represent different grade/educational levels and subjects follow:

- A first-grade teacher used this structure to teach animal classifications (e.g., what characteristics are associated with birds, reptiles, mammals, amphibians, and fish).
- A third-grade general and special educator teaching team created cards that constituted a number of different equations (e.g., cards representing these numerals, symbols, or operations: 2, (=),10, (×), 15, 12, (−), 13, (=), 120). When grouped in specific combinations, a correct solution was evident. When students correctly configured themselves in two groups of four, these equations were formed: 10 ×

12 = 120 and 15–13 = 2. The teachers could differentiate instruction easily by creating cards (and ultimately equations) that ranged in difficulty level. Some student groups could form algebraic equations, others fractions, and still others could represent the process of addition or subtraction.
- In a university level pharmacology course for physician's assistants, drug types identified by their generic names were placed on cards. Students were asked to classify themselves in multiple ways by the use of the drug, the side effects of the drug, and the populations of patients who benefit from its use.

Representation of *social constructivism*: A critical tenet of this theory is that knowledge or the way humans understand their experiences and reality is not simply constructed, it is co-constructed through the frameworks of language and culture in relationships among individuals. In this example social discourse is not only encouraged but required to make meaning of the academic content. The individual must seek out others to make deliberate comparisons, judgments, and analyses. In doing so, each interaction with another class member reveals new perceptions and interpretations, consequently shaping new knowledge that has been developed collaboratively within a unique social context. In addition, learners have multiple opportunities to interact with and learn from more competent peers during the interchange of information representing the zone of proximal development defined by Vygotsky (1978).

Representation of *social learning theory*: Social learning theory emphasizes that by observing others and engaging in reciprocal social and academic interactions the individual develops new and more complex behavioral and intellectual repertoires. The strategy Classify, Categorize, and Organize establishes an arena for individuals to observe the language and behavior of other group members while problem solving. Models are present as exemplars for appropriate attitudes, reactions to questions, and higher level thinking skills. Since students must integrate their knowledge and information and then convey it to the rest of the participants, there is opportunity to rehearse or practice new behavior.

Representation of *social interdependence theory*: Social interdependence exists when the outcomes of individuals are affected by the actions of others. The interactions that take place in the context of this collaborative learning strategy require and promote positive interdependence. To engage in the activity and ultimately be successful students cannot function in isolation. By sharing their knowledge and finding relationships between what is represented on their card and others', the individual is ultimately promoting the group's achievement of joint goals (i.e., to constitute a meaningful category that integrates each individual's contribution).

Representation of *social justice principles*: In this example students are placed in an empowering and "knowing" position at the outset of the learning experience. Rather than assuming the students are not knowledgeable and must be taught what is relevant from an instructor, students individually and then collectively must use their existing knowledge to discover and make personal meaning from the content. They are not passive recipients of instruction that is dictated by others but have significant agency in their own learning. The teaching/learning relationship is reoriented to one that becomes a dialogue first among students and then with the teacher who is informed by the students' discovery of new patterns and conceptions. Students have an equitable role in conveying relevant concepts alongside the teacher. This process promotes greater spontaneity in instruction and assures instructional time is not spent directly teaching what students already know or could discover.

Important Scientific Research and Open Questions

Research regarding collaborative learning strategies is generally subsumed under broader investigations of collaborative learning. If collaborative learning strategies are held distinct from *cooperative learning*, it is difficult to find studies that have extensively investigated the use of one particular strategy. Overall in reviews of research, outcome measures of achievement, reasoning, frequency of new idea generation, and transfer of content learned from one situation to another were found to be superior in collaborative learning approaches as compared to competitive or individualistic structures (Barkley et al. 2005; Johnson and Johnson 2005). Additionally, research examining the use of collaborative learning strategies as forms of differentiation in instruction and vehicles to promote the inclusion of students with disabilities in general education environments are being established (Udvari-Solner and Kluth 2007). It seems the critical research question is no longer: *Should* collaborative learning be installed in our elementary, secondary, and higher education classrooms? Instead the pertinent question arises: *When* should collaborative learning be selected over other approaches?

Collaborative learning is not a panacea for all instructional purposes. It is also wrought with potential downfalls in implementation, the learning process, and group dynamics. Ineffectively sharing information held by individuals to the group, social loafing, limitations in information processing and conflict resolution, and the ability to rectify failing projects have been documented problems (Kirschner et al. 2009). Consequently, an instructor must make conscious choices regarding the most appropriate instructional strategy to match the demands of an academic task. Kirschner et al. (2009) use *cognitive load to theory* to propose that the complexity of the task should influence the decision whether to use individualistic or collaborative approaches. On a basic level, *cognitive load theory* relates to the perceived mental effort expended by the individual under specific instructional conditions.

► It is, therefore, hypothesized that the more complex the learning task (i.e., the higher the intrinsic cognitive load), the more efficient and effective it will be for individuals to collaborate with other individuals in a manner that reduces this load. By contrast, less complex tasks that can easily be solved by a single individual will lead to less efficient learning in groups than in individuals alone, because the required group communication and coordination process (i.e., transaction costs) impose an additional cognitive load upon the group members, regardless of whether this communication and coordination is beneficial to learning or not (Kirschner et al. 2009, p. 37).

The critical message for teachers as they design assessment, curriculum, and instruction is that the learning activities designated for collaborative interactions should be complex enough in nature that they cannot be easily carried out by individuals. In addition, based on the replete research history, collaboration in learning carries with it opportunities to build valued academic skills concurrently with essential social skills that are required for complex human relationships. The key is not to make exclusive choices for one learning structure over another but to create a balance of experiences in the classroom that serves the needs of multiple learners well.

Cross-References

- ► Active Learning
- ► Collaborative Learning
- ► Collaborative Learning and Critical Thinking
- ► Collaborative Learning Supported by Digital Media
- ► Cooperative Learning
- ► Group Cognition and Collaborative Learning
- ► Group Learning
- ► Social Construction of Learning
- ► Social Learning Theories

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Collaborative Learning Supported by Digital Media

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Synonyms

Collaborative e-learning; Computer-supported collaborative work; Computer-supported cooperative work

Definition

Collaborative Learning Supported by Digital Media (CLSDM) is a teaching/learning strategy with digital media collaborative tools, used by interacting participants to change the state of collaborative products. CLSDM is used to generate evolving documents as a result of knowledge sharing, experience, and information sources in a scholar context.

Theoretical Background

Collaborative Learning Supported by Digital Media is used as an instructional framework to introduce collaborative learning experience (Cattafi and Metzner 2007); it is based on learning theories, and teaching and learning strategies incorporated into instructional design, group strategies, and collaborative tools. Consideration of instructional theories in the design of tools is referred as instructional design.

Learning and learning strategies are grounded on well-defined theories: constructivist, cognitive, and behaviorist theories (Schunk 1997). These define general concepts and contribute to a discipline of thought for theoretical comprehension as well as in the concept's application (Schunk 1997); however, they provide partial views since they generally focus on certain aspects of a learning situation.

The cognitive processing paradigm is based on the objectivist paradigm, which purports that knowledge (i.e., reality) exists independent of and external to the learner. Knowledge is a fixed commodity and, as such, can be measured and known objectively. If knowledge exists "outside" the learner, it is the task of the learner to acquire and retain an accurate representation. It is the task of the instructor to reflect or "mirror" reality (Jonassen et al. 1995). Behaviorism maintains that only external observable processes explain a behavior; therefore learning is the response behavior to a stimulus. The constructivist paradigm reflects a position that knowledge is not independent of the learner but is internally constructed by the learner as a way of making meaning of experiences. Research has found equality, collaboration, construction of knowledge, and learner control as variables associated with constructivist strategies (Miller and Miller 1999). A dominant characteristic of constructivist learning is collaboration among learners using technology tools to enhance communication through collaboration.

Teaching/learning strategies provide learners with experiences in a relevant context allowing them to transfer the acquired knowledge into a real context (Schunk 1997; Cattafi and Metzner 2007). Instructional design uses strategies aimed at the individual such as tutorials, training, simulation, up to date information, exploration, and goal-centered scenarios. Group strategies include forums, discussion, expert view, multiple perspectives, and informal collaboration. Instructors should identify needs and plan, implement, and assess classroom instruction through the collaborative use of technology and other resources (Willis 2006).

A learner has to interact with other learners, instructors, content, and the underlying technological platform. In order to contextualize collaboration as a teaching/learning strategy it is useful to classify interactions among participants as conversational, transactional, and collaborative. A conversational interaction is characterized by an exchange of information between two or more participants with the purpose of establishing a relation. A transactional interaction includes the exchange of transactional entities specifying the relation among participants (e.g., in a commercial context the exchange of goods or transactional entity for money defines buyer and seller roles). In a collaborative interaction, the main goal of participants is to change the state of the collaborative entity usually realized as a collaboration product such as a document or a diagram; the collaborative entity is evolving and will change state until it reaches a stable form as a consequence of the collaborative interactions. Collaborations conceptualized as "communities of learners" are supported by communication tools ranging from decision support systems to computer-supported intentional learning environments that permit learners to build knowledge databases (Jonassen et al. 1995; Schneider 1994; Wagner 1997).

The tools enabling collaborative strategies can be classified as supporting a method or supporting an area. Web-based tools can be viewed as communicational, collaborative, or teleconferencing tools. Communicational tools supporting collaboration rely predominantly on sending messages, files, data, or documents enabling information sharing among participants. Collaborative tools enable group work and they include Project Management Systems, Workflow Management Systems, Knowledge Management Systems, Extranets, blogs, online forums, wikis, podcasts, lifestreams, social bookmarking, Web communities, social networking, and avatar-based virtual reality. They are used in a wide spectrum of problem domains, including business computing. Teleconferencing tools enable interactive information sharing and each participant can set and access data in a shared blackboard; video and audio are used for information exchange, forums for asynchronous virtual discussions, and chat rooms are platforms for synchronous virtual discussions. Online conferencing and email are two technologies available and easy to use which has made them a tool of choice for collaborative courses (e.g., Jonassen et al. 1995; Warschauer 1997).

The key to implementing successfully these strategies lies in the analogy between mental structures and processes and the associative structure and hyperlinking processes of the Web. The challenge is to construct an instructional environment accurately reflecting the instructor's knowledge structure (Miller and Miller 1999).

Several guidelines for the successful application of a digitally supported teaching and learning strategy are proposed: establishing a highly structured, positive learning environment that encourages individual responsibility and creates high expectations, to teach collaboratively; creating spaces for learner collaboration and peer review; redefining the instructor's role; building a community; and exploiting time (Kuriloff 2005).

Important Scientific Research and Open Questions

Computer-Supported Collaborative Work, Groupware, Computer-Supported Cooperative Work, and Collaborative Learning Supported by Digital Media are frequently used as synonymous; however, this point of view is at least theoretically incorrect (Cattafi and Metzner 2007).

Computer-Supported Collaborative Work (CSCW) is a multidisciplinary research field dealing with the development of tools and techniques providing support to people performing shared tasks on a network or a distributed platform (Greif and Cashman 1988).

Although the terms "CSCW" and "Groupware" are generally used indistinctly, some authors point out that CSCW focuses not only on studying groupware tools and techniques but also its social, organizational, and psychological impact. Groupware applications integrate concurrent activities of users working on a single project connected on a network or Internet (Wilson 1995). It is worthwhile noting that "collaborative" and "cooperative" are sometimes used indistinctly in the definition of CSCW; however, some authors consider a semantic difference between these two concepts (Dillenbourg and Schneider 1995). Dillenbourg and Schneider argue the difference lies in how the tasks to be accomplished are decomposed: cooperative means tasks are decomposed hierarchically into independent subtasks; collaborative means tasks are decomposed hetero-hierarchically into interchangeable layers (Cattafi and Metzner 2007).

Coordination is a process used to exchange information among people using a common system of symbols, signs, and behavior, requiring a dependency management between activities and support of interdependencies among participants (Bordeau and Wasson 1997). Cooperation requires coordination when the results are to be integrated while collaboration is usually a synchronous process. Therefore, communication is essential in any coordination or collaboration activity.

In a wider context, Computer-Supported Collaborative Work, Groupware, Computer-Supported Cooperative Work, and Collaborative Learning Supported by Digital Media are considered teaching/learning strategies supporting Web education or e-learning, where all educational activities use digital media and software tools, and Internet is the communication platform. Computer-mediated communication involves the use of computer communication technologies to connect learners. It can be used in various forms in a teaching/learning process for content publication, support of administrative tasks, increasing availability via electronic tutorials and promoting collaborative learning by enhancing communication between learners and instructors. In Web education or e-learning, strategies can be collaborative or cooperative and encompass cognitive procedures for self-control and self-regulation applied by participants on attention, memory, and comprehension; in a collaborative form, activities are performed in the classroom – virtual or real – by small groups of learners after explanations of the instructor.

Information technologies supporting Web education or e-learning should have the following properties: accessibility, multiplatform, multimedia format for displaying information, graphical interfaces, group restricted access, hypertext structure of information and content, interpersonal communication, learner follow-up, tools for collaborative work, learner management and control, creation of evaluation and self-evaluation assignments, access to information and content on the Web, and interactions among group members. In e-learning the learning process is viewed in terms of the increasingly skilled participation of members in a knowledge-based community.

When developing a collaborative/cooperative project some degree of structuring groups is necessary. A structure is the result of an organization viewed as a social or administrative entity (Chiavenato 1999). As social entities, organizations consist of people having to reach some goals. Every goal requires work to be accomplished. The work is decomposed into tasks and assigned to members of the group. Formal organizations are based on a structure rigorously defined in official documents and on a rational division of tasks to be accomplished, specializing the functions and entities by activities. In informal organizations the structure emerges on the fly as an outcome of human relations based on friendship or antagonism between individuals playing specific roles in the underlying formal organization; hence, groups emerge that are not considered in the official documents (Cattafi and Metzner 2007).

As administrative entities, organizations are responsible for planning, integrating, structuring resources, creating entities, and assigning activities. According to the degree of formality of the relationships between the members of an organization, different kinds of organizational structures can be identified: bureaucratic, team, and spontaneous cooperation based on teams and collaborations. Whether communication strategies consider time elements (i.e., synchronous vs. asynchronous) allows classifying organizations as hierarchical, dynamic, and virtual (Whittaker et al. 2001). Each kind of organization shows different degrees of collaboration between its members (individuals or groups) when accomplishing their tasks (Cattafi and Metzner 2007).

As in any human endeavor, specific social or task factors can impact collaborative learning, and to be useful these factors should be measurable. Language and meaning can also impact the process of collaborative learning and tools. Additionally, collaborative learning could affect power relations in participants and influence performance. These power relations can be studied by allowing role changes of the participants.

Cross-References

► Collaborative Learning
► Computer-Based Learning Environments
► e-Learning and Digital Learning

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Collaborative Learning with Emerging Technologies

► Interactive Learning Environments

Collective Development and the Learning Paradox

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Synonyms

Innateness controversy; Novelty; Sociological model of learning

Definition

The learning paradox refers to a set of arguments that, in the 1980s, questioned the received way of conceptualizing learning. The core of the arguments was that novel knowledge cannot be derived completely from old knowledge, or it would not be new. Yet the new transcending part of it cannot be completely new either, for then it could never be understood. In particular, Fodor (1980) maintained that learning something genuinely novel is therefore impossible and that all essential structures must be present at birth. It appeared difficult to counter these objections and consequently this extreme Nativist position had a devastating impact on the popularity of theories of learning and development (e.g., Piaget's theory).

Collective learning refers to a conceptualization of learning that takes the structures and processes of social cooperation into account as a "reality sui generis" (Miller 1987). It is an alternative conceptualization of learning that promises to avoid the learning paradox. Collectively accepted knowledge is knowledge that cannot be denied and yet is not necessarily completely comprehended. It thus creates the possibility of experiencing contradictions without reference already to the subsequent level of understanding. The suggestion is that if we explain, in this social way, how a group of peers who seriously try to solve a dispute can understand a disturbance and can learn something genuinely novel, we are not invoking the contradictions alluded to in the learning paradox in our explanations.

Theoretical Background

The novelty problem was articulated by Fodor some 30 years ago. He provided a modern formulation of the ancient (Plato) learning paradox, making it relevant to learning and the conception of stage development as entertained by Piaget. He concluded that it is impossible to learn something fundamentally new. Novel knowledge cannot be derived completely from old knowledge or it would not be new. Yet the new transcendent element of it cannot be wholly new either, because then it could never be understood. In Plato's "Meno" dialogue, the paradox is brought forward by Meno but the arguments underlying it originated with the Sophists. They used the paradox to argue against the view that learning is an activity of learning persons themselves. They tried to convince their opponents that learning is completely dependent upon instruction. For if it were true that learning depended on asking and searching, learning would not be possible – asking for something means that you already know what you are looking for, in which case you do not need to learn it anymore. However, if you do not know it yet, you cannot learn it either, because then you cannot know what it is that you are looking for. Plato did not agree with the conclusion that learning is exclusively dependent on instruction. Although he admitted that some knowledge must be presupposed, he maintained that this knowledge could be dormant. The immortal soul already knows everything before being born; learning is a matter of recollection. More recently the same controversies have reemerged. Fodor (1980) maintains that learning something genuinely novel is impossible and therefore that all essential structures must be present at birth. Fodor is primarily concerned with the issue of concept learning, which he believes to be a confused notion. He claims that all learning theories are based on inductive extrapolation, and therefore must acknowledge hypothesis formation and confirmation among the processes involved in learning. He then shows that given such premises, there can be no such thing as concept learning, or achieving a new stage in development as Piaget would have it.

The line of argument entertained in such learning theories (specifically within the empiricist tradition), and Fodor's objections to it, can be reconstructed in three steps: (a) First, a subject has to have an idea of what he or she wants to learn. A representation of it (e.g., a hypothesis specifying a general rule) must be present: the input. (b) Second, the subject should test whether these ideas conform with experience. For example, the hypothesis must be put to test. That is why it has to be representable in the first place. Fodor's main examples involve concept learning. Testing would amount to verifying whether the concept is used correctly after the inference of a rule that specifies the right use. Correction, in this case, is carried out by other competent speakers. The predicate learned (novel knowledge) is only justified after confirmation of the hypothesis, so something is learned if and only if this step has been completed: the output of the learning process. (c) A problem of circularity will occur in the special case when the input and output are of the same kind. In this case, the learning process presupposes as input that which is only available as output. Fodor points out an instance of circularity. A problem arises when we want to learn a "primitive" concept (concepts having no further internal structure and hence not representable in terms of other concepts). It is impossible (by definition) to form a hypothesis about them without the use of the primitive concept itself. But since this is exactly the concept that is to be attained, the paradox follows (Fodor 1981).

Notice that all of the three steps or conditions are necessary for the paradox to occur. If one is omitted, there is no paradox. For example, if condition (c) is not met, it is perfectly possible that something is learned. Fodor admits that complex concepts might be learned because they can be represented initially by other (i.e., primitive) concepts (Fodor 1981, p. 271). Also, relative learning is possible because input and output are of a different order. The initially available cognitive structures are powerful enough to generate new hypotheses (new content), as long as these hypotheses do not transcend the boundaries of the present framework. As we will see, Miller's solution of the Meno paradox is also based on a definition of the input as of a different order than the output, such that condition (c) does not apply. If there existed a form of learning in which conditions (a) or (b) were not required, the paradox likewise would not follow. If a test and confirmation are not required to learn something truly new, a representation is not necessary prior to the acquisition of the new knowledge. In the absence of condition (b), the emergence of a representation of something novel and learning something novel are the same phenomenon. The attainment of a mathematical insight might be an illustration of such a learning step. It may be unclear how such a step can occur, but there no longer exists a paradox! Note, therefore, that Fodor's (1980) basic argument that it is impossible to represent a richer logic in terms of a weaker logic, while being true, is not sufficient to allow the conclusion that learning a richer logic is impossible. Only if learning is defined in such a way that step (b) is indispensable is this conclusion warranted. Fodor is very clear about this because he adds: "if what you mean by learning is hypothesis formation and confirmation" (p. 148). Of course, giving up the notion of confirming the new insight is a heavy price to pay to avoid the paradox. But it is logically possible that a form of learning exists that involves neither hypothesis formation nor confirmation. Fodor (1981) does not subscribe to the empiricists' account of learning. Instead, he maintains that all primitive concepts (and fundamental structures) must be innate, although he admits that experience plays a role by triggering the concepts. Triggering is considered to be a causal process and for that reason not a form of (constructive) learning. In this way Fodor avoids the paradox.

We now turn to another account of learning, based on the idea of internalization as advanced by social interactionists. Chapman (1992) proposed that joint activity in which subjects come to share the knowledge that each alone possesses can lead to the construction of new knowledge neither individual possessed before. Such an idea has been worked out originally and fairly elaborated by Miller (1987).

Miller claims that it is possible to experience disturbances in a relevant and meaningful way without reference to the subsequent level of understanding. However, this is only possible, according to him, by means of discussion by a group of peers who seriously try to solve a dispute. Miller maintains that cognitive development can be explained adequately only if the structures and processes of social cooperation are taken into account as a "reality sui generis" (Miller 1987). In collective argumentation – which is the model for all argumentation – the primary goal is to develop a joint argument that answers a disputed question by relating it to collectively accepted knowledge. Of greatest relevance is a discussion between peers sharing the same developmental level. On the basis of theoretical considerations as well as empirical research, Miller states that under such circumstances a disturbance can be understood and something novel can be learned. He claims that such collective arguments are regulated by a very specific set of rules and more specifically three cooperation principles. These three basic cooperation principles of argumentation can be in operation (in some form) between very young subjects. They function as a coordinating device that determines the processes of argumentation in such a way that, in principle, a set of collectively valid statements can be found and agreed upon. The principle of generalizability specifies that a statement is justified if (a) it is either immediately acceptable (belongs to the collectively valid) or (b) if it can be converted to the collectively acceptable. The principle of objectivity states that if a statement cannot be denied (i.e., its denial cannot be converted into a collectively valid statement), it belongs to the realm of the collectively valid, whether it confirms or falsifies the point of view of some participants. The principle of consistency forbids that contradictions enter into – or (once they have been discovered) remain in – the realm of the collectively valid (Miller 1987). These conditions governing collective argument are much more restrictive than those governing individual thinking. An isolated individual could easily ignore conflicting information. However, in a collective argument this is not acceptable as long as the goal – developing a joint argument that gives an answer to a disputed question – is retained.

Assuming these principles are indeed in operation, it is conceivable that one participant in the argument asserts proposition A while another participant asserts proposition B, with both statements mutually exclusive and both traceable to the same shared base of collectively accepted knowledge. Consider the well-known balance scale task. If two or more children address this problem, one child may claim that the one arm is heavier due to a greater number of weights, while another child maintains that the other arm is heavier because of the greater distance of the weights from the fulcrum. Since both children are at a stage in which they acknowledge only one of the variables, they must in principle be able to understand each other's reasoning (albeit with difficulty). What they were unable to do is to coordinate both points of view and to see their interconnectedness. The conclusion that Miller draws from this example is that a child can no longer simply ignore what is going on and is bound to experience some form of contradiction. At least he or she will be made aware of the fact that his or her current knowledge is not sufficient to reach a consensus (Miller 1986). Collectively accepted knowledge is knowledge that cannot be denied and yet is not necessarily completely comprehended. It thus creates the possibility of experiencing contradictions without reference to the subsequent stage.

Important Scientific Research and Open Questions

The learning paradox posed a huge problem for developmental psychology and learning theories. An alternative to individualistical, psychological theories of learning was felt to be needed by many. Yet, approaches just stressing the social character of learning often do no more than shift the problem of novelty to the sociocultural plane. In that case, either all novelty is denied or novelty remains unaccounted for. For example, if children learn new ways of thinking from their parents and their parents have learned them from their parents, and so forth, we get an infinite regress. Miller (1986) offered a far more interesting version of a Vygotskian social approach based on collective learning principles.

However, despite the huge impact on developmental psychology and learning theories the learning paradox is not a hot topic any more. Interactionism has become more fashionable, partly due to nonlinear dynamic systems theory (Molenaar 1986). It is accepted nowadays that interactions in a dynamic system may lead to the emergence of new structures and sudden reorganizations. That reorganization can take place quite suddenly and have rather severe consequences is not only possible, but even plausible for systems as complex as the human mind. Although Fodor's strict functionalism has lost much of its credibility and interactionism is nowadays conceived of as much broader than just collective argumentation – for example, from the neuronal to the social level – the fundamental questions involved in the learning paradox should not be ignored because otherwise they will undoubtedly return in some new form.

Cross-References

- ▶ Bootstrapping: How Not to Learn
- ▶ Can Children Learn by Bootstrapping?
- ▶ Collaborative Learning
- ▶ Collaborative Learning and Critical Thinking
- ▶ Collective Learning
- ▶ Conceptual Change
- ▶ Cooperative Learning
- ▶ Piaget, Jean
- ▶ Plato
- ▶ Social Construction of Learning
- ▶ Socio-Constructivist Models of Learning

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Collective Knowledge

▶ Collective Learning

Collective Learning

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Synonyms

Collective knowledge; Learning networks

Definition

Collective learning is a complex concept that is variously defined. It is generally conceptualized as a dynamic and cumulative process that results in the production of knowledge. Such knowledge is institutionalized in the form of structures, rules, routines, norms, discourse, and strategies that guide future action. Learning emerges because of interactive mechanisms where individual knowledge is shared, disseminated, diffused, and further developed through relational and belonging synergies. Collective learning can therefore be conceived as an evolutionary process of perfecting collective knowledge.

Theoretical Background

The concept of collective learning draws on a wide body of theory related to learning, organization theory, sociology, and psychology. It recognizes the role of social interactions in the construction of values and identity. Collective learning may result in a communal language, in which collective approaches and knowledge are expressed and cultivated. Garavan and

McCarthy (2008) highlight a multiplicity of concepts that fall within the rubric of collective learning, including organizational learning; the learning organization; team learning; communities of practice; collective knowledge and memory; and collaborative learning. Collective learning, therefore, represents a macro concept that addresses learning at the levels of the team, the organization, and society. An important distinction is made between individual learning and collective learning. Individual learning tends to be conceptualized as an information system where learning is interpreted, retained, and retrieved by individuals. Collective learning is viewed as a more macro-level concept that emphasizes the synergy and advantages of the collective element.

Collective learning has been defined in a variety of ways. It is possible to view it as an aggregate of individual learning. According to this perspective, collective learning occurs when individuals create, acquire, and share unique knowledge and information. A second perspective suggests that collective learning is assumed to occur when a collective engages in behavior such as asking questions, seeking feedback, experimenting, reflecting, and discussing options and errors. Another view suggests that collective learning is a dynamic process in which learning process and the behavior of the collective change as the collective learns.

This third view considers the collective to be an open, living system that continuously interacts with its environment. Many collectives are structured; however, others are unstructured, yet they take on characteristics of complex, living entities. Collectives are essentially self-organizing through their interactions with the environment. Collectives can be both closed and open. Some components do not change whereas others are transformed.

Central to collective learning is the notion that the collective is enhanced in three ways: (a) it achieves the capacity to restructure and to meet changing conditions; (b) it can add and use skills, knowledge, and behaviors; and (c) it becomes highly sophisticated in its capability to deal with feedback and reflect on its actions. Evolutionary theory defines learning as a process of cumulative knowledge, taking place in firms where common and shared rules exist which allow individuals to coordinate their action in search for problem solutions. The social element embedded in the collective process differentiates collective learning from individual learning.

Different types of collective learning are highlighted in the literature:

- Aggregate learning is conceptualized as the aggregation of learning gained though trial and error at the individual level. The emphasis is on individual learning processes rather than any collective perspective. Aggregate learning may give rise to fragmentation and individualization rather than inclusion and collectivity.
- Group learning focuses on the processes that a group uses to acquire new skills, knowledge, ways of interacting, change patterns between group members, standard operating procedures, and behavioral routines.
- Institutional learning is conceptualized as learning that institutions undergo in order to meet their public brief or mission. It is a form of learning that enables the institution to function effectively; however, it may lead to institutionalized practices such as hierarchy, paternalism, and authority.
- Associational learning is conceptualized by high symbolic complexity, but low levels of structural openness. It focuses on the coordination and synthesis of cognitive structures of associated individuals and groups. The emphasis in associational learning is on collective identity.
- Double contingency learning is conceptualized as a process of social or discursive construction that delineates a field of experiences. It involves the erection of boundaries and the exclusion of others. It may result in situations where consensus is expected, disagreements are avoided, and, in some cases, it leads to a form of fundamentalism.
- Triple contingency learning is characterized by both structural openness and symbolic complexity. This learning occurs due to the emergence of discourses, cognitive forms, and the capacity to observe, challenge, evaluate, and form opinions. It has strong self-constituted and self-organized characteristics.

Collective learning is considered valuable for individuals, organizations, and societies. The outcomes of collective learning may be both individual and collective. Commentators such as Simons and Ruijters (2001) consider collective learning to be collective in the sense of process and outcomes. Their restrictive definition has, however, been broadened by other researchers to accommodate individual learning process with collective outcomes.

Important Scientific Research and Open Questions

From a theoretical point of view, there is much to be done to further develop the concept of collective learning. Collective learning processes potentially include a variety of perspectives such as a cognitive and/or behavioral focus; whether learning is individual learning within the collective or genuine collective learning. The factors that facilitate collective learning are not yet fully understood. The role of learning networks, for example, are highlighted as important because they provide physical or virtual platforms for human interactions (Fu et al. 2006).

Camagni (1991) suggests that collective learning is not simply the acquisition of information, and that the availability of information is not a central issue. Instead, it is the process by which available information becomes useable knowledge that is the main focus. Organizations within the innovative environments seek to cope with the problem of uncertainty by developing a "transcoding function" that translates external information into a language that the organization can understand. Crucial to this process is the emergence of a common language and culture that act as preconditions to enable this transcoding to take place. Further research may be required to understand the shared cognitions that facilitate collective learning. The term cognitive consensus has been used in relation to shared cognition and collective learning. Cognitive consensus refers to the degree of similarity among the mental models by members of the collective. This consensus increases over time depending on the level of interaction. The role of trust is also important in terms of the extent of social interaction and the extent to which a shared cognition will emerge expediently (Capello 1999).

Camagni (1991) distinguishes between "links-based" and "non-links-based" mechanisms by which this common language or shared cognitions emerges. In the context of organizations and firms, of particular importance on the links-based side are supply chain linkages or links established via the movement of labor between firms. Non-links-based forms of learning include imitation, emulation, and reverse engineering. This perspective proposes the belief that, while knowledge is central to the competitive success of the organization and while the existence of linkages and emulation is important for this to occur, linkages or emulation do not simply transfer knowledge directly. Instead, they are part of the social context in which learning occurs and new knowledge is generated within the organization. Therefore, particular phenomena such as localized interfirm networks and spin-offs and intra-regional labor mobility become crucial focuses of attention and indicators of the possibility of innovation and learning.

The conditions that facilitate collective learning are largely hypothetical and primarily focused on analogies to individual learning and on experience. Nonaka and Takeuchi (1995) refer to a number of conditions that stimulate collective learning, including the presence of a vision which directs the processes of knowledge creation, an avoidance of information, and a creative focus which stimulates interaction with the environment. Recent theories on innovation, mainly from cultural–individual perspectives, focus on supportive conditions for collective learning including learning skills, learning motivation, and collective foreknowledge.

The distinction between individual learning and collective learning requires more detailed investigation. Both concepts share elements of continuity and dynamic synergies; however, they differ in terms of the social nature of the latter process. Commentators highlight the public dimension of collective learning. The mechanisms for transfer of learning focus on ratings and behaviors. The operationalization of collective learning is, therefore, problematic and researchers are faced with significant problems concerning how best to measure it or identify and label it as a social construct.

Cross-References

▶ Collective Development and the Learning Paradox
▶ Communities of Practice
▶ Cooperative Learning
▶ Group Learning
▶ Organizational Learning
▶ The Learning Organization

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Commitment

► Motivational Variables in Learning

Commitment for Learning Goals

► Volition for Learning

Common Understanding

► Concept Similarity in Multidisciplinary Learning

Communal Learning

► Group Learning

Communication

► DICK Continuum in Organizational Learning Framework
► Discourse
► Discourse and the Production of Knowledge
► Social Interaction Learning Styles

Communication and Learning in the Context of Instructional Design

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Synonyms

Listening; Reasoning; Thinking

Definition

Learning may take place through self-discovery, by accident, through observation, by reading, or through communication with another individual. This description focuses on purposeful teaching/training of an individual or group, using principles of instructional design. Learning is the purposeful adoption of an organism's behavior to its environment based upon insight gained from encounters with the environment directly or communication that provided the insight.

Somewhere between the two fields of communication and learning lies a blend, an opportunity for the creative, entertaining stimuli of communication theory to merge with teaching/training materials to offer to learners instructional tools that are at once both rigorous and pleasurable. The result is a measurable outcome where one knows that learning/training took place effectively and efficiently, while at the same time the learner/trainee comes away from the event with a warm positive feeling, ready to expand ones learning and tackle even more difficult scenarios.

Theoretical Background

Beginning in the 1960s, elements of what today is called "instructional design" coalesced from components in education, experimental psychology, educational learning theory, and industrial psychology. Early work by Robert Gagné and Leslie Briggs laid the groundwork for others who followed at Florida State University. Because these researchers were rooted in hard scientific backgrounds, and used that perspective to develop their teaching/learning paradigms, some of the softer, humanistic aspects of interpersonal interaction may have been accidentally slighted. Among the casualties might have been communication and its relationship to learning. Some of the fundamental resources that provide extensive background on the interrelationships between communication and instructional design include works by (Briggs 1979); (Dick and Carey 1990); (Gagné 1985); (Kaufman and Grisé 1995), and (Keller 1987).

Building on the notion of system thinking (Capra 1996; Wheatley 2006; Senge 2004) a deeper understanding of the holistic nature of learning and communication begins to pull together. All pieces are connected and impact all others. It is this communication between beings that enables learning to arise. As we intensify our study by turning to one another, clarity and wisdom may bring about understanding and perhaps even harmony.

Important Scientific Research and Open Questions

Leslie Briggs once remarked that the essence of instruction (for purposes of the teaching/learning paradigm) was to "Tell the learners about what you are going to teach them, then teach them, then tell them what you taught them" (personal conversation 1969). This is a more straightforward way of describing David Ausubel's concept of advanced organizers, wherein the learner is stimulated to become aware that he/she was about to be taught something which would consist of specific elements for a specific purpose. Bob Gagné (1965–1992) also carefully dissected the teaching/learning process into the necessary condition of learning to ensure that instruction would take place.

Sadly, all of these works have an element of sterility to them. The emphasis of experimental design on the process cannot be mistaken. Conversely, marketing and advertising domains – created to persuade people to act in certain predictable ways – do not integrate the rigor of instructional design but rely more on group dynamics and interpersonal communication. The inclusion of system thinking with its outcome-based orientation has done much to move teaching/learning theory toward a humane application of principles that are valuable and functional for learners.

Communication and learning needs to pay heed to ongoing research with nonhumans. Current studies with dolphin (Viegas 2010) demonstrate that mammal sea creatures have astonishing levels of intellect and creativity, and are readily able to understand, problem-solve, empathize, and otherwise demonstrate "human" characteristics.

Cross-References

► Communication Theory
► Discourse
► Discourse and the Production of Knowledge

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Communication Anxiety

► Apprehension and Communication

Communication Aversion

► Apprehension and Communication

C

Communication Theory

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Synonyms

Conversation; Information transmission; Language; Listening; Message; Speech; Statement

Definition

Communication must be seen as a two-way street. A stimulus is provided, and upon reception on the part of another species, a reaction (appropriate or inappropriate, overt or implicit) takes place. When speaking of *communication*, so far it is still essential that both participants are living organisms, not electromechanical or other devices. The day fast approaches where artificial intelligence provided through computers *may* adequately integrate thinking and feeling behaviors to qualify as communication.

Communication's definition lies in two parts: there is a transmitting or sending organism, often times referred to as the encoder. The encoder encodes the message to be delivered. A recipient organism, often referred to as the decoder, receives the message. Much processing, with many components, takes place in the transmission between the two beings, and components of that transmission are an essential ingredient to the definition of the communication process.

Theoretical Background

The Communication Process

Person A has a notion within his/her mind to make a statement and then vocalizes that statement (or otherwise issues forth a symbolic message – such as through sign language). This is referred to as *encoding*. The *encoder* selects a method of transmitting the statement, be it via live and in person voice, or telephone, meaningful symbols, written or electronic message – or even body language. That transmission selection feature is referred to as the *coded channel* of communication. Note that not all transmission channels are always overtly selected by the encoder, some happen automatically and possibly without control of the encoder (body language is a good example of an automatic channel of transmission that might provide substantial information to the astute decoder). The majority of the transmitted message is usually conveyed via channels other than the direct verbal presentation, with much research indicating that up to 80% of a received message is ultimately delivered by nonverbal means (again, such as body language).

The recipient of the transmitted message is the *decoder*, who when stimulated to pay attention to the situation, translates and interprets the message into a meaningful statement – at least as far and they personally are concerned. In an ideal setting, the communication loop is completed by the decoder encoding a new feedback message back to the original encoder, demonstrating reception and interpretation. Much or even most of the initial intended information of the message may often become distorted or lost, or misconstrued at this point. While there may be a common language and dialect shared between the encoder and the decoder, the degree to which they do not share a common *frame of reference* can be critical in disorienting or otherwise confounding the meaning. The degree to which encoder and decoder operate from different frames of reference (when perceiving how things happen – people, governments, religions, gender, etc.) will reduce the ability for the message to be translated and interpreted in the manner anticipated by the encoder.

Coding of the message evolves in three forms: *Language* itself – the verbalization used; *paralanguage* – delivery of the verbalization: tone, pitch, rate, emphasis, volume; and *nonverbal cues* – including body language, gestures, posture, use of eye contact and facial expressions, and so on. Interestingly, research over the past quarter century has consistently demonstrated that about two-thirds of the meaning of a message is actually carried through nonverbal and paralanguage codes – not the spoken words of the message! So communication functions on levels that are much more fundamental than vocabulary. The notion of not looking a gorilla or a bear or a lion in the eye is much more than idle chatter. The intended recipient of a message may be tuning in on all channels!

In completing the communication loop, decoders should make their best attempt to respond to the encoder with their most accurate translation of what they perceive was transmitted. This feedback enables a series of successive approximations to close in on a harmonious understanding of what the message was supposed to be. In reality, such feedback looping rarely occurs, leaving less than an ideal communication event.

Additional communication hurdles are presented by both *internal interference* and *external interference*, in every situation. These interference features are sometimes referred to as *noise*. Internal interference arises when the decoder is physically or emotionally distracted. This may arise from a headache, pressing matters of one's schedule, concern for an ill family member, or other distractions. Additionally, a value judgment may be made by the decoder as to whether he/she wishes to believe/accept/appreciate the message being transmitted. This can be because the encoder is a person of another gender, another race, another culture, a working subordinate, a lost love, or a host of other rejections. By external interference we mean confusion caused by the external environment – quite literally, *noise*.

Important Scientific Research and Open Questions

Communication holds a special place within psychology, education, and other social sciences. It is a practical application of a variety of disciplines, melded together to be a functional device for living organisms. Because communication is such an inherent element of society and culture, its roots and complexity are often overlooked. Now in the twenty-first century, the definition demands leaping beyond all-too-frequent perspectives such as a process of conveying ideas, and thoughts, and feelings between people.

B.F. Skinner's *operant conditioning* methodology requires an observable change in behavior caused by an event. The stimulus-response (S-R) observation may be covert and not readily seen – such as change in blood pressure, galvanic skin response, retinal dilation, and so on. The "skinner box" was often used within experimental psychology to trigger responses in an organism. This is not communication.

Let the loop be closed here so that the definition expands beyond humans to include other animals formerly referred to as "dumb" animals. Situational observation and experimentation routinely demonstrate, for example, that animals possess problem-solving skills, and can exhibit empathy. Following are three of an endless array of examples of creatures other than humans communicating with one another, engaging higher order reasoning processes that move the interchange from a pure S-R pattern to a communication scenario.

1. A dog is hit by a vehicle on a busy highway. He is crippled. Another dog observes the cries for help and comes to his assistance. He pulls his "friend" out of harm's way. See YouTube, December 3, 2008. http://www.youtube.com/watch?v=m2qSakxWt54
2. Animal psychologist Joyce Poole, from Cornell University, and others are conducting elephant listening projects in Kenya, Africa, as well as central and western Africa. We have learned that elephants routinely emit subsonic (to humans) utterances that can be distinguished by other elephants more than a mile away. These vocalizations are in addition to the sonic vibrations that elephants make by stomping the ground and in turn detecting those vibrations through their feet at a considerable distance. See CBS Television "60 Minutes, January 3, 2010," and National Geographic (2003). http://news.nationalgeographic.com/news/2003/02/0221_030221_elephantvocal1.html
3. A pet, be it a cat, a dog, or another creature, routinely responds to its owner's requests, not always in the manner desired (the same can be said of children). There is no question on the part of the human "master" that the animal is not simply performing an S-R conditioned response pattern such as Pavlov's dog salivation experiments (English publication 1927). The communication that exists is at a much higher level than S-R patterns. Pets truly can conduct nonverbal dialog with their owners and others. This interplay should be considered a form of communication, as we shall see through the expanded definition.

Although many other examples of animal communication can be cited (e.g., dolphin and primate research), for simplicity's sake, the definition of communication shall be described by actions and reactions between people.

Functional Definition of Communication

It is time to take a new look at the functional definition of *communication*. It is time to embrace communication features that are very real and take place daily in human to human contact, in human to other species contact, and in other species to other species contact.

One last mention should be made regarding the functionality of external sounds within a communication setting. Often unbeknownst to a film audience, a movie director is employing long-understood principles of the psychological impact film music can have on an audience. "Film music" refers to more than the melody carried by music, but also the background effects that are brought to play which might further the message of the film. One example is the application of subsonic or very low pulsation softly in the background to raise the tension level in an audience. A rather sublime scene can move viewers to a feeling of uneasiness, not by what is seen on the screen, or even by the words or melodic track, but by the foreboding rumble that strikes up an innate fear response. Another classic example of communication impact within a movie, without the use of words is music itself. Alfred Hitchcock's classic film "Psycho" (1960) rivets the audience in fear as violins strike up a screeching noise as the slasher cuts through the shower curtain, killing the bathing Janet Leigh. Proof of the subliminal impact communicated is easily demonstrated by replaying the same scene without audio. A much more innocuous murder takes place.

To Recap and Add a Touch of Philosophy

A message that intends to convey meaning is communicated by an encoder using one or more channels to transmit a message. A decoder absorbs the elements presented as best as possible, interpreting through the filters and experiences of his/her own frame of reference, paying attention to language, paralanguage, and nonverbal cues. Ideally, the decoder will respond to the encoder with their interpretation of the meaning, seeking validation, or obtaining redirection/correction. Additionally, within a communication setting, internal and external stimuli often create distraction/noise.

Woven throughout the definition of the communication process is an essential element – listening! For all the encoding, decoding, and feedback loops to function, success of the communication depends upon a situation wherein both parties are unobstructedly listening to each other, not assuming, second guessing, ignoring, but earnestly working on maintaining a focus between one another. Age, gender, culture, attitude, etc.: life gets in the way. Communication requires work.

The more one studies communication, the more awareness is gained regarding how imprecise and accidental communication between two individuals really is. Through improved communication skills, people can and must do a better job sharing experiences and working in harmony, rather than remaining antagonistic based upon misunderstandings.

From the 1967 Paul Newman film *Cool Hand Luke*, the phrase "What we've got here, is a failure to communicate" became a symbol for culture clashes. Communication across racial, religious, cultural, and ethnic lines is essential. Retired US Senator Bob Graham, chair of the United States Commission on the Prevention of Weapons of Mass Destruction Proliferation and Terrorism noted that failure of communication between various US intelligence agencies enabled the terror of 9/11 to take place. Had better communication existed between cultures, perhaps the War on Terror would find itself to be unnecessary.

Cross-References

► Communication and Learning in the Context of Instructional Design
► Discourse
► Discourse and the Production of Knowledge

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Communication Training for Health Professionals

► Empowering Health Learning for the Elderly (EHLE)

Communities of Practice

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Communities of practice are groups of people who wish to learn something by collaborating with other members of the group both in real and virtual world. These people share a goal or interest and learn from each other by sharing information and experiences. The term originates from Jean Lave and Etienne Wenger (1991) and has since spread into other fields of learning research, including second language learning.

Lave and Wenger (1991) characterize learning as a legitimate peripheral participation in communities of practice. They examine learning is distributed among participants of the communities. In their view, learning is an integral part of generative social practice in the lived-in world (p. 35). Learning can be explored as a legitimate peripheral participation. When a person becomes a member of communities of practice, he or she gradually transforms into a practitioner, a newcomer becoming an old-timer and/or a novice becoming a practitioner, a member of community of practice in which all the tasks, skills, and knowledge can be learned. Wenger (2006) emphasizes three important characteristics of community of practice:

1. *The domain*: A community of practice is not only a club of friends or a network of connections between people, it can be defined as a domain of interests like a shared competence that distinguishes members from other people. Members of the community therefore value their collective competence or knowledge and learn from each other.
2. *The community*: In the Dictionary.com Web site, community is defined as "a social group of any size whose members reside in a specific locality, share government, and often have a common cultural and historical heritage." but community of practice has something more than this definition. Members of community of practice engage in joint activities and discussions, help each other, share information, and most importantly learn from each other. On the Internet, a Web site alone is not a community of practice. Also, having the same job or the same title does not make for a community of practice unless members interact and learn together. Members of communities of practice do not have to work together or be together on a daily basis (Wenger 2006, p. 2). Sharing their ideas and thoughts on the same subject and developing themselves through those ideas and thoughts make them a member of community of practice. Learning from each other might be verbalized as the base of communities of practice in this context.
3. *The practice*: Members of a community of practice are practitioners and their aim is to develop themselves and learn from each other. They develop a shared repertoire of resources: experiences, stories, tools, and ways of addressing recurring problems in their shared practice. Practicing together to learn from each other, face to face or at a distance in a small or large group, might be verbalized as another base of communities of practice in this context.

Application of the concept of community of practice has been found in business, organizational design, education, government, professional associations, development projects, and civic life.

Cross-References

► Situated Cognition
► Situated Learning

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Community of Learners

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Synonyms

Schools-within-schools; Small learning communities; Small schools; Smaller learning communities

Definition

Community of Learners is a general term used to refer to the concept of grouping individuals to support collective and individual learning. The phrase has been associated with professional learning communities (PLCs), but this entry examines its association with small learning communities (SLC), a product of the small schools movement. A small learning community is any separately defined, individualized learning unit within a larger school setting. Students and teachers are scheduled together by community and frequently have a common area of the school in which to hold most or all of their classes (Wasley et al. 2000).

A small learning community is a school reform initiative aimed at addressing issues caused by large comprehensive high schools' bureaucratic school organization, fragmented curriculum, and impersonal climate, especially in urban settings. Sources of substantial funding for smaller learning communities have come from several philanthropic organizations as well as the US Department of Education's Smaller Learning Communities (SLC) Program established in 2002. The program awarded discretionary grants to local educational agencies to support the implementation of SLCs and activities to improve student academic achievement in large public high schools with enrolments of 1,000 or more students. This funding was provided in response to early research findings that suggested small schools could potentially narrow achievement gaps between White middle class, affluent students and ethnic minority and/or poor students (Cotton 2001).

SLCs are usually created from the division of large comprehensive high schools into smaller communities, employing structural as well as strategic reforms aimed at addressing concerns about at-risk student populations. Restructuring methods common among SLCs include: small learning clusters, "houses," career academies, magnet programs, or schools-within-a-school. SLCs may also employ strategic reforms aimed at changing daily operations within a school that either complement the structural reforms or are used alone. Some common strategic reforms include: block scheduling, freshman transition academies, advisory or adult advocate systems, academic teaming, multiyear groupings, common planning time for teachers and other innovations designed to create a more personalized high-school experience for students (U.S. Department of Education et al. 2008).

SLCs have been credited with enhanced student outcomes on several measures including: decreased dropout rates, increased promotion rates, increased number of graduating seniors planning to attend college, increased attendance, lower incidences of school violence, and increased participation in extracurricular activities (Cotton 2001; Kahne et al. 2008; Levin 2010; U.S. Department of Education et al. 2008; Wasley et al. 2000). Outcomes related to increased academic achievement and engagement have been modest or neutral (Kahne et al. 2008; Lee and Smith 1999; Marks 2000; Shouse 1996).

Theoretical Background

The benefits of small schools were first established in Barker and Gump's (1964) seminal study examining the relationship of affective outcomes with school size in Kansas. They concluded that small high schools foster a sense of community among students that promote opportunities to participate in extracurricular activities and exercise leadership roles. Additionally, SLCs provide for repeated contacts between teachers and students, between teachers and parents, and among students that result in the establishment of strong social bonds across all of a school's stakeholders.

A systematic focus on student learning, often referred to as academic press, has also emerged as a key characteristic of successful SLCs. Academic press is defined as the extent to which school members (administrators, teachers, and students) emphasize conformity to the norms and values associated with academic excellence. The theory behind academic press is that students will achieve more when expectations for academic learning are high, what they are supposed to learn is made clear, and they are held accountable for their academic performance (Lee and Smith 1999). Unfortunately, in schools that enroll substantial proportions of low-achieving students, students may become alienated when academic standards are raised beyond what they can reasonably attain. Smaller learning communities address this issue by fostering a school culture that emphasizes high expectations for academic performance, while providing the social supports necessary for students to meet those expectations. Findings from several research studies suggest that when students experience academic press and strong social support concurrently, they perform better on achievement tests than when they report experiencing high levels of either construct alone (Lee and Smith 1999; Wasley et al. 2000; Cotton 2001; Marks 2000; Shouse 1996).

Most research on SLCs, and small schools in general, suggests that school size is not the proximate cause of the improved student outcomes. Instead, school size is said to facilitate the development of school characteristics associated with positive student outcomes. Cotton's 2001 comprehensive analysis of SLCs identified several characteristics of successful SLCs grouped into five categories:

- Self-determination: The ability to make decisions regarding building usage, scheduling, budget, curriculum, instruction, and personnel in order to establish a distinct identity.
- Identity: A common sense of vision and mission around enhanced student learning as well as an in-depth focus on a particular theme that distinguishes an SLC from the larger building in which it is housed.
- Personalization: Focus on the social relationships developed among teachers and students, as well as substantive efforts to involve parents and the community.
- Support for teaching: Includes a variety of strategies that enhance the role and decision making authority of teachers, including bottom up decision-making structures, job-embedded ongoing professional development, teaching teams, and the implementation of integrated curricula.
- Functional accountability: Incorporating authentic performance assessments that measure what students can do as well as what they know, in addition to standardized tests for gaging student learning. Additionally, the use of non-traditional accountability measures such as measures of teacher efficacy, commitment, and collective responsibility for student learning that provide time for the SLCs structures and strategies to take effect in measureable ways.

Important Scientific Research and Open Questions

Early research on SLCs has focused on the extent to which SLCs are successfully implemented, issues facilitating and inhibiting implementation of SLCs, as well as on the nature of the various structural methods and strategic reforms SLC schools employ. A study commissioned by the US Department of Education examining implementation of SLCs found that SLCs were most often implemented as career or freshmen transition academies and were moderately implemented based on criteria such as: common planning time for teachers, autonomy over program policies and staffing decisions, the availability of course offerings related to a given theme, and career related graduation requirements. There are several factors commonly identified as facilitating SLC implementation and sustainability including: strong school leadership, supportive central administration, high levels of staff buy-in, and sufficient space to make SLCs separate and distinctive. However, scheduling and logistical issues, lack of physical space to separate SLC programs, and lack of qualified staff to accommodate smaller class sizes are commonly described as having a negative influence on SLC implementation and sustainability.

Research aimed at associating enhanced student outcomes with SLC conversions have focused on attendance, graduation rates, student engagement, and academic achievement. In his examination of extant research on the impact and challenges of SLCs, Levin (2010) examined findings from four separate SLC evaluative studies. Three of the four studies examined identified significant increases in attendance rates of SLC schools contrasted to comparison schools. In the studies that had at least one cohort of students reach graduation, there was evidence suggesting SLCs had higher graduation rates than comparison schools. However, there is not yet a critical mass of research examining SLCs with cohorts having reached graduation and, thus, conclusions about whether they impact graduation rates are tentative at best.

Most research at the present cannot provide sufficient evidence either to support or refute SLCs as a means for improving academic achievement. Three of the four studies Levin (2010) examined did not identify statistically significant differences between SLC schools and comparison schools on academic achievement defined by performance on standardized math and reading tests. However, there was modest, but statistically significant improvement in middle and high schools' achievement in one study where SLCs had been implemented for 8 years, the longest of any of the studies examined.

The existing research examining the impacts of SLCs has several limitations that should be noted. First, most studies do not include comparison groups or base line data to contrast with SLC outcomes. Additionally, often SLCs are implemented in conjunction with other reform efforts, and thus it is difficult to isolate the SLC structure as the cause for any improvement identified.

As SLCs mature as a school reform measure, several challenges to its promise to promote the educational success of at-risk populations have emerged. Proponents claim that SLCs allow teachers time to collaborate on instructional improvements and relationships with students; however, collaboration among teachers has mostly focused on addressing SLC logistical issues or data analysis of standardized test scores. Teachers spend much less time reforming curriculum and instruction in meaningful ways such as team teaching and curriculum integration than on student behavior management. Despite being granted autonomy, SLCs often are still subject to pressures from the district, state and national level regarding testing and accountability implications. The result is often a lack of substantive change in the approach to teaching and learning; leaving SLCs as small versions of the large schools they are designed to replace.

Proponents of SLCs suggest that the structure can better match individual students' interests, learning styles and career ambitions. SLCs can tailor the curriculum, instructional approach, and school culture, to the specific interests of the student population. However, the variety of SLCs, in terms of themes and instructional focus, may also pose challenges for ensuring consistent levels of rigor across SLCs. When students are given a choice of SLCs, their selection is usually based on, "the extent to which they were willing to let high school make demands on their time and effort" (Ref., p. 121), and thus resulted in stratifying high and low performing students based upon SLCs' reputations (Lee and Ready 2007). The allocation of teaching staff by teacher preference can have a similar impact. For example in one reorganized SLC, teachers who previously worked in an International Baccalaureate program all chose to work in the same SLC and thus attracted academically high achieving students while another SLC chosen by coaches and athletic staff attracted student athletes.

Newly formed SLCs must also transcend school history. Stand-alone small schools are often founded in new buildings with new faculties and create new norms rather than challenging old ones. However, SLCs are often situated in low performing schools using the existing building and employing the same faculties and staff. Thus, school norms, patterns of relationships, and community expectations of the school are difficult to change. Levin (2010) suggests that stakeholders explicitly discuss the challenges and pitfalls of history so that SLCs may be better able to attain a level of change that includes altering patterns of student learning.

Research that demonstrates the impact of SLCs on students over longer time frames is needed. Additionally, research examining how SLCs successfully navigate pressures from the division, state, and national levels and sustain curriculum and instructional reform in the face of high stakes testing and accountability should be undertaken. Finally, research comparing the effectiveness of the various strategies and structures SLCs employ incorporating baseline data or comparison groups should be conducted so that what works about SLCs is more clearly elucidated and communicated.

Cross-References

- ► At-Risk Learners
- ► Interests and Learning
- ► Learner-Centered Teaching
- ► School Climate and Learning
- ► Small Group Learning
- ► Student-Centered Learning
- ► Workplace Learning

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Comparative Cognition

► A Salience Theory of Learning
► Learning in Invertebrates
► Linguistic and Cognitive Capacities of Apes

Comparative Music Education

► International Perspectives in Music Instruction and Learning

Comparative Psychology and Ethology

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Definition

Comparative psychology and ethology are both sciences which study animal behavior, typically nonhuman behavior, though both have often studied humans. Comparative psychology is a subdiscipline of psychology and ethology of biology. Both can trace their roots to the late nineteenth century. Depending on which history one reads, the first comparative psychologist was Pierre Flourens, a protégé of Baron Cuvier, or George John Romanes, a friend and student of Charles Darwin. Flourens' book title represented the first use of the term, comparative psychology (*Psychologie Comparée* 1864) and predated Romanes' *Animal Intelligence* (1882). Both proposed a science that would compare animal and human behavior, Romanes postulating the existence of a gradient of mental processes and intelligence from the simplest animals to man – the comparative approach much in use today. Romanes strengthened his proposal by a vast collection of anecdotal accounts of clever behavior in dozens of animal species. Though perhaps best known today for the fallacies of his anecdotal method and for his easy assignment of human mental faculties to animals – anthropomorphism – Romanes nevertheless succeeded in establishing his idea of a gradient of mental processes across the animal kingdom as a basic premise of early comparative psychology. Ethology too has a mixed parentage. Isidore Geoffroy-Saint-Hillaire first used the term in 1859, though Oskar Heinroth, a late nineteenth century German biologist, was one of the first to apply the methods of comparative morphology to animal behavior; he is thus considered to be one of the founders of ethology.

Both disciplines had many adherents in the early and middle parts of twentieth century: Comparative Psychology in the USA under the influence of the learning psychologists (e.g., Ivan Pavlov and Edward Thorndike), the behaviorists (e.g., Zing-Yang Kuo, John Watson, and B. F. Skinner), and the epigeneticists (e.g., T. C. Schneirla, Daniel Lehrman, Ethel Tobach, and Gilbert Gottlieb), while Ethology became firmly established after World War II in Europe under the influence of biologists such as William Thorpe, Nikko Tinbergen, and Konrad Lorenz. The latter two, in fact, were awarded the Nobel Prize in medicine (there is no separate prize for behavioral research) in 1972 for their animal behavior studies (they shared this prize with Karl von Frisch, an early twentieth century biologist).

Theoretical Background

Given the biological roots of both comparative psychology and ethology, evolution was seen to play an important role in behavioral origins by both disciplines, though in different ways. Comparative psychology, strongly influenced by early twentieth century Functionalists (e.g., William James, John Dewey), believed behavior allowed organisms to adapt to their environments (i.e., Darwinism); behavior itself was not an evolved phenomenon, though the organism was. Thus, as organisms changed through evolution, new or different behavioral potentials arose. Ethologists, on the other hand, understood behavior itself to be an evolved process, the route being genes –> instincts, or inherited behaviors. In later years, this one-way route, from genes to behavior, became to be known as the central dogma of molecular biology. Additionally, while comparative psychology tended to engage primarily in laboratory research, ethology emphasized the significance and importance of studying behavior outside the laboratory, in natural settings.

These two fundamentally different approaches to the study of behavior lead to a serious intellectual and theoretical "war" around the 1950s. Ethology advocated the position that behavior was a biological phenomenon, *determined*, and not merely *influenced* by the organism's genotype; much animal behavior was thus believed to be instinctive. Indeed, Lorenz, whose mentor was Oskar Heniroth, and Tinbergen spelled out the full meaning of what instinctive behavior was. The clearest statement of this is found in Tinbergen's book, *The Study of Instinct* (1951). Comparative psychologists, on the other hand, tended to take an epigenetic approach, stressing the importance of development, experience, and other psychological processes. The differences were summarized in an important paper by Daniel Lehrman (1953), which today still represents one of the best critiques of instinct theory. While healthy, the ensuing debates settled little. It was an important 1966 book by Robert Hinde (*Animal behaviour: A synthesis of ethology and comparative psychology*) that seemed to resolve the differences between these two opposing views. Indeed, a later 1981 book by the ethologist S. A. Barnett (*Modern ethology: The science of animal behavior*) was able to discuss the discipline without resorting to instinct explanations.

Important Scientific Research and Open Questions

The two disciplines historically sparred over the nature–nurture issue: Was behavior a biological or a psychological phenomenon? Endless debates over this issue have yet to see it formally resolved. Contemporary reports of the discovery of a gene for a behavior are routinely retracted following failures to replicate such findings – but the search continues. This is as true in psychology as it is in biology, though many in both camps understand behavior to be a biopsychosocial phenomenon. The significance of both psychological and biological development, long ignored, is now seen to be crucial to a full understanding of behavioral origins. While focusing primarily on issues of comparative psychology, the many open questions still confronting the study of animal behavior are reviewed in a recent textbook (Greenberg and Haraway 2002). For example, though studied now for well over 100 years, there are still new developments to be found in the area of learning.

Current Status

While comparative psychology grew in America, ethology remained somewhat stagnant in Europe. Many still identified with the discipline, though it was clear that they had abandoned the hard-nosed biological determinism of the classical ethologists. Beginning in 1944 with the initiation of the American Psychological Association's divisional structure, comparative psychology had a home in Division 6, Physiological Psychology and Comparative Psychology. In the 1990s, in an effort to attract new members, the division entered into discussion of a name change – the important point for the present discussion was the retention of "comparative psychology" in the new name adopted at the 1995 APA meeting, Behavioral Neuroscience and Comparative Psychology. While membership in Division 6 was falling, comparative psychology as a field of study remained healthy as illustrated by the appearance of several comparative psychology societies in the closing years of the twentieth century: The Southwestern Comparative Psychology Association (founded in 1983 by Michael Domjan, Del Thiessen, Steve Davis, and Gary Greenberg); the Comparative Cognition Society (founded in 1994 by Ron Weisman, Mark Bouton, Marcia Spetch, and Ed Wasserman); and the International Society for Comparative Psychology (founded in 1983 by Ethel Tobach and Gary Greenberg). An even earlier group, the International Society for Developmental Psychobiology, was founded in 1967 by George Collier, Norman Spear, Bryon Campbell, John Paul Scott, and others. The annual and biennial meetings of these societies attract animal behavior researchers from several disciplines across the globe; their membership is also international. There are, of course, several other such societies in countries around the world.

The picture was not so rosy for ethology which seemed to languish in the same period. This was likely because, "The simple truth is that ethology never did deliver as a science of comparative behavior..." (Plotkin 2004, p. 105). Indeed, in 1989 ethology was declared:

> dead, or at least senescent. That is, if you think of ethology in the narrow sense – the study of animal behavior as elaborated by Konrad Lorenz, Nikolas Tinbergen, and Karl von Frisch. It has been quiescent for some time. No exciting ideas were emerging, and data gathering on key issues had lost its direction. (Barlow 1989, p. 2)

However, the biological study of animal behavior has thrived well into the twenty-first century. Ethology was reborn in the early 1970s as a new science, that of sociobiology (Wilson 1975), the goal of which was to biologicize the social sciences. But this blatant attempt at understanding animal and human behavior as a purely biological phenomenon was met with scathing criticism (Hull 1988; Lustig et al. 2004) from numerous quarters. The main point of contention centered around the continuing nature–nurture issue and the question of whether behavior, especially human behavior, was the result of genetic and biological determinism. To many opponents of sociobiology, psychology was not a biological science at all, but a uniquely psychological science (e.g., Greenberg 2007).

The intellectual sparks flew for years, well into the end of the twentieth century, which witnessed the appearance of a still new iteration of ethology, evolutionary psychology. This approach focuses primarily on human behavior and posited that we owe our universal nature to evolutionary adaptations faced by our Pleistocene ancestors that we have inherited in our genomes. A good source for reviewing the tenets and the research conducted in this field is *The Handbook of evolutionary psychology* (Buss 2005). With evolutionary psychology, instincts are once again in vogue. As with ethology and sociobiology, evolutionary psychology is not without its critics (e.g., Lickliter and Honeycutt 2003). It is not the application of evolution to behavior that is at question, but the manner in which it is understood to apply to behavioral origins. Evolutionary psychology, though seen by many to be seriously flawed, is a rather popular orientation in the contemporary behavioral sciences. After all, what serious scientist in 2011 can object to the significance of evolution to psychology?

There has also been new life breathed into ethology and sociobiology. The sociobiological idea of the genetic basis of human altruism has recently been somewhat retracted by one of its earliest proponents, E. O. Wilson. While this is comforting news to many non-reductionistic comparative psychologists and other animal behaviorists, it does not sit well with all students of behavior (Marshall 2010), attesting to the staying power of the classical ideas of ethology. In a recent analysis, Salzen (2010) makes a case for interpreting the ideas of ethology in modern neuroscientific terms. There is in fact a discipline known as "neuroethology," which describes animal behavior in terms of how the nervous system works. As a comparative psychologist, I take comfort in the staying power of my discipline. Its history has been long, though not nearly as tumultuous as that of ethology.

Cross-References

► Animal Culture
► Biological and Evolutionary Constraints of Learning
► Developmental Cognitive Neuroscience and Learning
► Evolution of Learning

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Comparative Psychology of Learning

► Evolution of Learning

Comparator Hypothesis of Associative Learning

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Synonyms

Comparator theory; Performance-focused model; Response rules; Retrieval-focused model

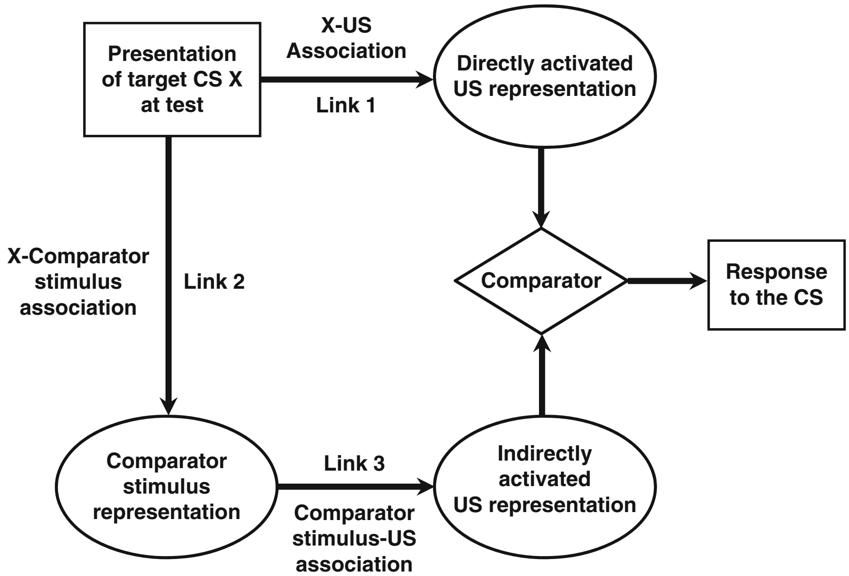
Definition

The central tenet of the Comparator Hypothesis is that responding to a cue requires that the cue signal a change in reinforcement. That is, given prior cue-outcome pairings, responding to the cue is not a direct function of the strength of the outcome representation activated by the cue. Instead, responding depends on the degree to which the cue predicts an increase (or decrease) in the likelihood of the outcome relative to the likelihood of the outcome in the training context (which might differ from the test context) in the absence of the cue.

Theoretical Background

Both early theorizing and prevailing contemporary models of learning (e.g., Rescorla and Wagner 1972) posit that responding to a cue in a Pavlovian situation reflects the degree to which a cue activates a neural representation of the outcome. However, there are a number of observations that challenge that simple assumption. Most notably, studies of contingency found that behavioral control by a cue depends not only on the probability of the cue being followed by the outcome (p[outcome|cue]), but also on the probability of the outcome in the absence of the cue, that is the context (p[outcome|context alone]). Thus, behavioral control by a cue seemingly reflected p(outcome|cue) – p(outcome|context alone). Initially, it was unclear whether the critical context was that of training or test, and whether the computation occurred after each training trial or at the beginning of each test trial. But subsequent research determined that the critical context was that of training and that this computation occurred at the time of each test trial.

Miller and Matzel (1988) used these two findings to formulate, in associative terminology (as opposed to conditional probabilities), the original Comparator Hypothesis, which went well beyond contingency theory by allowing nontarget cues that were present during target training (not only the training context) to serve as the basis of comparison (i.e., as comparator stimuli). This provided a new account of cue competition (e.g., overshadowing and blocking) as well as the contingency phenomena on which the model was based. Prior accounts of cue competition assumed that cue competition is caused by a failure to acquire the target cue-outcome association. When the pairings occurred in the presence of another cue, the most common account asserted that the two cues competed for a limited amount of available associative strength that could be supported by the outcome. The Comparator Hypothesis instead assumes that each cue acquires an association with the outcome independent of the presence of the other cue. The impaired behavioral control of the target cue after it is trained in compound with a nontarget [comparator] cue is a consequence of a comparison between the target cue-outcome and comparator stimulus-outcome associations; each serves as the context of learning for the other. However, as testing of the target can occur in the absence of the comparator stimulus, activation of the comparator-outcome association must be mediated by activation of the target cue-comparator stimulus association (see Fig. 1). Thus, the Comparator Hypothesis states that behavioral control by a target cue is a direct function of



Comparator Hypothesis of Associative Learning. Fig. 1 The Original Comparator Hypothesis. Learning by contiguity (not total error reduction); Responding by modulation, which is the basis of stimulus interaction

the target-outcome association (Link 1) and an inverse function of the product of the target-comparator stimulus association (Link 2) and the nontarget cue-outcome association (Link 3). Critically, this account views cue competition as something that influences expression rather than acquisition of associations. Hence, the Comparator Hypothesis is centrally a response rule, with acquisition governed by a simple local error reduction rule, that is, a learning mechanism that reduces the predictive error of each cue separately, rather than the overall predictive error of all cues present on a given trial.

Great flexibility was obtained by allowing comparator stimuli to be either a punctuate companion cue or a protracted training context. The Comparator Hypothesis so framed readily accounts for cue competition effects, all of which depend on strong associations both between the target cue and the competing cue (Link 2, with the competing cue serving as the comparator stimulus) and between the competing cue and the outcome (Link 3). Additionally, the reduced behavioral control by the target cue seen as a result of presentations of the outcome alone during target cue training and the outcome-preexposure effect are consequences of a strong training context-outcome association; the requirement that this be the training context (not the test context) in order to establish Link 2 also explains the context specificity of these effects. The reduced behavioral control by the target cue seen as a result of CS-alone presentations (i.e., CS-pretraining exposure, partial reinforcement, and extinction) is viewed as a consequence of strengthening of Link 2, with the training context serving as the comparator stimulus.

The Comparator Hypothesis not only anticipates excitatory responding to the target cue when Link 1 is strong compared to the product of links 2 and 3. It also anticipates behavior indicative of condition inhibition when Link 1 is weak relative to the product of Links 2 and 3. In contrast with traditional associative models, the Comparator Hypothesis does not posit negatively valued associations or associations between cues and no-outcome representations. Rather, all associations are positive (i.e., excitatory), and behavior indicative of conditioned inhibition arises from an interaction among positive associations. This is a strength of the Comparator Hypothesis, as it obviates perplexing issues concerning encoding of information that supports behavior indicative of conditioned inhibition.

The Comparator Hypothesis, unlike prior models of learning, avoided using a learning mechanism dependent on total error reduction (i.e., a discrepancy between the outcome that occurs on a trial and the expectation of the outcome based on all cues present on that trial). Because cue competition is viewed as modulation of performance, rather than modulation of acquisition that is governed by total error reduction, the Comparator Hypothesis was the first model to account for retrospective revaluation. Retrospective revaluation (as an empirical phenomenon) refers to a change in responding to a cue as a consequence of a change in the associative status of another cue that was previously paired with the target cue. Such demonstrations are challenging for many models of learning because they assume that a cue must be present for a change to occur in its behavior control. Most demonstrations of retrospective revaluation consist of decreasing the associative status of the target's comparator stimulus (i.e., the cue with which the target was trained) and observing an increase in responding to the target. The best known example of retrospective revaluation is recovery from overshadowing. Following overshadowing of a target cue by a nontarget cue (by reinforcing them in compound, which results in reduced behavioral control by the target relative to its being reinforced by itself), extinction of the nontarget cue increases behavioral control by the target.

Although the Comparator Hypothesis provided the first coherent account of retrospective revaluation, alternative accounts (e.g., Van Hamme and Wasserman 1994) were soon developed that viewed retrospective revaluation as the consequence of changes in the value of the target-outcome association during the retrospective revaluation trial despite the absence of the target cue. The Extended Comparator Hypothesis (Denniston et al. 2001), which elaborated the Comparator Hypothesis, made predictions that differentiated its approach from that of the new acquisition-focused models. The changes in the Extended Comparator Hypothesis relative to the original Comparator Hypothesis were twofold. First, it allowed multiple comparator stimuli to summate in down modulating responding to a target cue, whereas the original Comparator Hypothesis assumed that only the companion cue with the strongest association to the target cue would serve as a comparator stimulus. Second, the Extended Comparator Hypothesis not only assumed that Link 1 was down modulated by the product of Links 2 and 3 as in the original Comparator Hypothesis, but that Link 2 (now Link 2.1) was down modulated by the product of Link 2.2 (the association between the target cue and a third cue) and Link 2.3 (the association between this third cue and the [first-order] comparator stimulus), and Link 3 (now Link 3.1) was similarly down modulated by the product of Link 3.2 (the association between the [first-order] comparator stimulus and a third cue) and Link 3.3 (the association between this third cue and the outcome). Although these changes seemingly complicate the Comparator Hypothesis, they actually simplify it by eliminating the arbitrary assumptions that there can be only one comparator stimulus and that Link 1 was special in being potentially down modulated, whereas Links 2 and 3 were immune to this process. In the Extended Comparator Hypothesis, all stimuli and associations are treated equally. The consequence of potential higher-order comparator stimuli is that a second-order comparator stimulus can reduce the effectiveness of a first-order comparator stimulus, just as a first-order comparator stimulus can reduce responding to a target cue. Thus, a post-target training change in the associative status of a second-order comparator stimulus should produce a change in behavioral control by the target cue in the same direction as the second-order comparator. This contrasts with changes in the associative status of a first-order comparator stimulus, which ordinarily induce a change in behavioral control by the target cue in the opposite direction.

Stout and Miller (2007) provided a mathematical implementation of the Extended Comparator Hypothesis. In addition to formalizing the Extended Comparator Hypothesis, this implementation added a feature. Both the original Comparator Hypothesis and its extension assumed that the product of Links 2 and 3 are always subtracted from Link 1 yielding so-called negative mediation (e.g., cue competition). However, phenomena like second-order conditioning and sensory preconditioning suggest that, under some circumstances, the indirect pathway from the target cue to the outcome (i.e., Link 2 and Link 3) adds to the direct pathway (i.e., Link 1) yielding so-called positive mediation. The mathematical implementation assumes that the determinant of the type of mediation is whether the organism has had sufficient opportunity to discriminate between the directly and indirectly activated representations of the outcome. With few training trials, the discrimination is difficult, so the two outcome representations summate. When there have been sufficient trials to facilitate the discrimination, the product of Links 2 and 3 is subtracted from Link 1 rather than added.

The Extended Comparator Hypothesis makes predictions that differentiate it from acquisition-focused models of retrospective revaluation. Notably, when a target cue has two (as opposed to one) comparator stimuli that are themselves associated, each comparator stimulus can act as a first-order comparator for the other comparator, thereby reducing the effect of the other comparator on the target cue. Thus, two treatments, each of which independently decreases responding to a target, collectively can result in more behavioral control by the target than with either treatment alone. For example, a target cue having two blocking cues as comparator stimuli can evoke stronger responding than the same target with only one blocking cue. These so-called counteractions are widely seen. Often the context serves as one of the competing cues. For instance, degraded contingency and overshadowing counteract; that is, context-outcome pairings, relative to context-alone trials, when interspersed among target–outcome pairings, reduce responding to the target, and compound cue trials reduce responding relative to elemental cue trials. But compound cue trials interspersed with context-outcome trials result in stronger responding to the target than either response reducing treatment alone. Counteraction has also been reported between cue-preexposure and overshadowing, trial massing and overshadowing, and long duration cues and overshadowing. Moreover, counteraction has been reported between treatments that enhance excitatory behavior control such as second-order conditioning supported by a context as the first-order cue and second-order conditioning supported by a punctuate stimulus as the first-order cue. Counteraction has also been reported between two inhibitory treatments (Pavlovian conditioning inhibition training and differential inhibition training, Urcelay and Miller (2008)).

Important Scientific Research and Open Questions

The Comparator Hypothesis anticipates changes in behavioral control of a target cue to occur as a result of both posttraining associative deflation and inflation of its comparator stimulus. Deflation is readily seen to increase responding to the target, whereas inflation's decreasing responding to the target is more elusive. Seemingly, animals are relatively resistant to losing previously acquired behavioral control, a conservative evolutionary strategy. To circumvent this problem, studies have been performed in which the target cue is not made biologically significant until after inflation. In this situation, retrospective revaluation is seen to result from both posttraining associative deflation and inflation of comparator stimuli. This confirms the basic prediction of the Comparator Hypothesis, but does not integrate into the model proper an account of why posttraining inflation of comparator stimuli does not work well in first-order conditioning.

The Comparator Hypothesis is designed to explain elemental learning and interactions between cues (and outcomes) trained in compound. However, the Comparator Hypothesis does not explain stimulus interference, that is, interactions between stimuli (outcomes or cues) trained apart.

The Comparator Hypothesis is a trial-wise model that assumes information processing necessary for responding occurs at the beginning of each test trial and information processing necessary for new learning occurs at the end of each trial. That is, it is not a real-time model. Hence, it is unable to account for a number of timing effects.

Cross-References

► Associative Learning
► Context Conditioning
► Pavlovian Conditioning

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Comparator Theory

► Comparator Hypothesis of Associative Learning

Comparison Task

A comparison task requires the observer to mentally imagine whether two objects could be rotated into congruence with each other. The mental rotation can take place in the three dimensions, and the experimenter can include distractor shapes by scrambling the shape in a different way or creating a mirror image of the item. The participant must therefore exclude the plausible alternatives and detect the correct choice.

Compartmentalization in Learning

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Synonyms

Inconsistency; Inflexibility

Definitions

There are three relevant definitions for the term compartmentalization depending upon the content in which it is used.

Definition 1 (Based on the Concept of Conceptual Schema)

The term "compartmentalization" is used in the sciences of learning and cognition to designate the phenomenon that occurs when an individual has two or more *different, potentially conflicting conceptual schemas* concerning a particular domain in his/her *cognitive structure*. Certain situations trigger one schema and other situations stimulate another. Compartmentalization is evident, by and large, when a given situation does not activate the schema that is most relevant to the specific situation and, instead, activates another – plausibly less relevant. One way to understand the notion of conceptual schema is, following Seel in this volume, as representing a particular way of organization of the generic and abstract knowledge a person has acquired in the course of numerous individual experiences with objects, people, situations, and events.

Definition 2 (Based on Representations)

This definition of compartmentalization is used more extensively in the field of *mathematics* education, since mathematical concepts are accessed, processed, and transmitted only through *semiotic representations*. Applied to representations, the phenomenon of compartmentalization reveals the *cognitive difficulty* that arises from the need to accomplish flexible and competent conversions back and forth between different types of mathematical representations of the same concept. These cognitive difficulties reveal deficiencies in representational flexibility, which indicate a fragmentary mathematical understanding of the relevant concept.

Definition 3 (Experimental-Operational)

From a statistical perspective and based on the idea that compartmentalization refers to the splitting up of an idea or concept into (sometimes more or less incongruent) parts, compartmentalization is the phenomenon of the establishment of two distinct clusters that correspond to different mathematical conceptualizations or different representations of, or different cognitive processes related to, the same concept which have a weak statistical relation (correlation, implication, similarity) between them.

Theoretical Background

Psychologists, cognitive scientists, and philosophers have all contributed toward theories on the architecture of mind. Some key constitutive notions of these theories are modules and modularity of mind. Fodor (1983) examines the modularity of mind and the extent to which the nativist thesis and the alleged domain specificity of cognition are relevant to constraints on the architecture of the mind. He argues that the input systems or perceptual modules as well as the system for processing language are domain-specific, encapsulated, mandatory, fast, hardwired in the organism, and have a fixed neural architecture. As Fodor states informational encapsulation is at the heart of modularity. However, Fodor forcibly argues that the brain apart from its input systems is not modular either in structure or in function since processing in certain domains is not informationally encapsulated from information in other domains. The processes in the higher cognitive centers, that is, the cognitive areas minus the input systems, are holistic in the sense that the knowledge stored in the system can affect all sorts of processing. All beliefs in the system are formed within the background of the total body of knowledge stored in the brain. In other words, there are no higher cognitive functions that are not affected by cognitive functions elsewhere in the brain and, thus, there are no compartmentalized areas of knowledge; the mind is not modular and cognition is massively abductive – abductive inferences are inferences to the best explanation. Equivalently, there are no higher cognitive systems whose function relies only on information stored in their proprietary data-bases. Instead, these functions depend on information stored everywhere in the brain.

Raftopoulos (2009) claims that even in the case of the perceptual system the distinction between perception and cognition is not as clear cut as Fodor thinks in so far as locations in the brain that participate in perceptual tasks also participate in cognitive tasks, although they perform different functions in each case.

Karmiloff-Smith (1992) has examined the question "Is the initial architecture of the infant mind modular?" and criticizes Fodor's ideas. In her model of representational redescription (RR) she describes the way procedural knowledge is initially represented and processed and then modularized and again becomes explicit and non-modular following her four Phases of Modularization. Karmiloff-Smith's theory is that modularity is the result of ontogenetic and not phylogenetic processes.

There is a possible parallel here between the modular theory of mind and compartmentalization. Compartmentalization is not indicated only by the inconsistency of one's behavior due to the activation of different schemas. Sometimes, in a given situation the schema that is the most relevant to the specific situation is not activated and instead, another plausibly less one is. Compartmentalization represents the act of partitioning an idea or concept into (sometimes more or less incongruent) distinct components and, in an attempt to simplify things, trying to impose thinking processes that eventually impede attempts to allow these components to connect again. Thus, several authors describe compartmentalization as the implicit or explicit knowledge that is automatically activated in everyday life and operates independently of other forms of knowledge. This phenomenon is described as knowledge compartmentalization (Schoenfeld 1986). A distinction is made between at least five types of knowledge compartmentalization that differ with regard to their effects on further learning and knowledge application. These are discussed below.

The Compartmentalization of Correct and Incorrect Concepts

In this case instruction does not replace the incorrect ideas by the correct concepts, but just provides additional pieces of knowledge; correct and incorrect knowledge coexist. The major deficiency resulting from this kind of knowledge compartmentalization is that in situations where only the use of the correct concept enables problem solving, the problem solver often depends on the old inadequate misconceptions and not on the scientific concepts he/she has recently developed which would be more appropriate (Mandl et al. 1993).

The Compartmentalization of Several Correct Concepts

Different concepts that are closely associated are acquired as separate pieces of knowledge and are stored in different compartments. This causes oversimplifications on the application of these knowledge structures because their complicated interconnections are not reachable. This kind of compartmentalization results in limited understanding and oversimplification in knowledge application (Mandl et al. 1993).

The Compartmentalization of Symbol Systems and Real World Entities

This concerns the lack of connections between symbol systems and real-world entities. In mathematics learning, for instance, this kind of knowledge compartmentalization causes students to manipulate symbols in a meaningless and mechanical way without understanding their relevance to their everyday activities. Consequently, on the one hand, students do not use real-world knowledge in solving arithmetical problems in school, and, on the other hand, they do not use school mathematics in their everyday life (Mandl et al. 1993).

The Compartmentalization of Representations

The ability to identify and represent the same concept in different representations, and the flexibility in moving from one representation to another allow students to see rich relationships and develop deep understanding of a concept. Weak connections or even a complete lack of connections among different types of conversion (i.e., with different starting representations) of the same mathematical concept is the main feature of the phenomenon of compartmentalization of representations and indicates that learners do not construct the whole meaning of a particular concept and have not grasped the whole range of its applications. This inconsistent behavior can also be seen as an indication of students' several views that different representations of the same concept are completely distinct and autonomous mathematical objects and not just different ways of expressing the meaning of a particular concept. In other words, students confuse an "object" or a concept with its semiotic representation (Elia and Gagatsis 2008).

The Compartmentalization of Strategies

Finally, it can be assumed that strategy compartmentalization refers to the difficulties in using multiple strategies and switching between them. This kind of compartmentalization can impede successful problem solving.

Important Scientific Research and Open Questions

Research in mathematics education has investigated the notion of compartmentalization with respect to various mathematical concepts, such as the addition or subtraction of natural numbers, the addition of fractions, the concept of function, the equation of the axis of symmetry of a parabola, etc. Among these studies, according to Definition 1, the following behavior could be considered as evidence of the existence of compartmentalization: first, learners inconsistently or incoherently deal with the same mathematical concept; second, a schema or thought process less relevant to the situation is activated in the learners' minds. Similarly, according to Definition 2, the following behavior could be considered as evidence of the existence of compartmentalization: First, learners inconsistently or incoherently deal with the same representation in different contexts or with different representations of the same concept. Second, a mental representation less relevant to the problematic situation is activated in the learners' minds as it is evident from the type of external representation used by the learner in problem solving.

On the one hand, further research could be done to the direction of "measurement" of the above mentioned behavior in relation to Definitions 1 and 2. In particular, further research could be done in relation to some statistical methods such as the hierarchical clustering of variables, the implicative statistical analysis, and the confirmatory factor analysis (Elia and Gagatsis 2008) in order to finalize the statistical indexes of the existence or not of the phenomenon of compartmentalization. In other words the research should contribute to the operationalization of Definition 3.

On the other hand, further research could be done about the role of the learners' and context's characteristics on the extent to which learners exhibit compartmentalized behavior. Since learning a concept can be accomplished through a process of "de-compartmentalization" that allows students to see the various interrelations between various aspects of the same concept, it is important and useful to examine what kinds of instructional conditions and approaches can prevent or alleviate compartmentalized ways of thinking in specific domains, such as mathematics.

Compartmentalization can be identified in various learning domains, concepts, and cognitive processes (i.e., use of strategies, representations). A major challenge to research in compartmentalization is therefore to propose and validate a comprehensive detailed framework for systematically describing and investigating this phenomenon.

Cross-References

► Schema(s)
► Semiotics and Learning

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Compassion

► Altruism and Health

Competence

► Learner Characteristics and Online Learning

Competence Development

► Comprehensive Learning

Competence-Based Knowledge Space Theory

A mathematical psychological framework for domain and learner knowledge representation that is applied for personalising learning paths and adaptively assessing knowledge and competence in the context of adaptive learning systems and adaptive educational games.

Cross-References

► Activity- and Taxonomy-Based Knowledge Representation

Competency-Based Learning

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Synonyms

Ability-based; Learning; Learning object; Performance; Prescription

Definition

Competence is a skill which is acquired. It is described by a certain set of tasks which can be executed if one has the relevant expertise. This set of tasks can contain subsets of different types of tasks. "Task," in fact, does not refer to the colloquial use of the word, but rather the exact description of a particular action scheme (e.g., for adding). Competence consists of one or more degrees of competence which indicate how well these tasks can be performed and describes a skill with a certain degree of sustainability, i.e., it should – if it is a characteristic of a person – survive for an extended period of time.

However, despite broad use of the concepts "competence" and "competency" in educational literature, the terms are not explicitly defined and, therefore, the question of how to differentiate these terms still remains topical.

Theoretical Background

There is neither a standard method for describing competencies nor a universal definition of "competency." We (e.g., Schott and Azizi Ghanbari 2008) propose a definition of competency which is – in our opinion – appropriate for educational research. To this end, we turn to Schott's (1992). "Appropriate" means that the competencies to be determined should be as desirable as possible for the educational system, as well as sufficiently describable, conveyable, and verifiable.

If – as in the definition above – "competency" consists of a set of tasks and competence levels, an accurate description of competency is a problem of appropriate task analyses. According to Schott's work on task analysis (e.g. Schott 1992), it is useful to split each task into states and changes and to take into account that the concept of "task" includes the following elements:

1. *Task name* (what the task is called, e.g., "adding," "first aid").
2. *Task objective* (what the task is, e.g., "applying first aid to a health problem," "summing up several numbers by means of a rule of calculation"): The task objective describes the deeper structure of the task.
3. *Task representation* (the manner in which a task is represented, e.g., "73 + 25 = 98" or "if you add LXXIII and XXV, you obtain LXXXXVIII"): The task representation describes the surface structure of the task.
4. *Basic formal structure as scheme of change*: Every task describes an operation as a change: It can be broken down into an initial state (the question), a final state (the answer/solution), and an operator which transforms the initial state into the final state. For a more detailed description, intermediate states may be specified. Given that such an operation of change can never be repeated in exactly the same way, it is always a scheme of change.
5. *Proficiency* (how well a problem is solved): A degree of competence can be specified in quantitative terms (e.g., 90% of the solutions are correct) or qualitative terms (e.g., certain facts have to occur).
6. *Degree of resolution* (the level of detail of the task description): Tasks can be broken down into subtasks or combined to form higher-level, complex tasks: The former increase the degree of resolution of the description, whereas the latter decrease it.
7. *Content aspect* (the subject of the task execution): The content aspect of a task may be inferred from the initial state and the final state of the task.
8. *Behavioral aspect* (the measure of executing the task): The behavioral aspect of a task, its operator, can be inferred from the change from the initial to the final state of the task.
9. *Contextuality:* The context of each execution of a task may vary. A distinction is made between an internal variation of the scheme of change describing a task and an external variation, which is related to the situational circumstances in which the scheme of change is implemented.
10. *Universality*: There are no range limitations concerning which operations can describe tasks. Tasks are not limited only to cognitive tasks.

The lack of a generally accepted operational definition of competence/competency is generally acknowledged. Some authors simply accept this fact and support a pragmatic approach. Stoof et al. (2002) label the search for an overarching definition of the term an objectivist approach in which the "criterion for a competence definition is not whether the definition is true but the extent to which the constructed definition has proved to be adequate in the context in which it is used (i.e., viability)" (p. 347).

In the literature, many definitions of competence/competency can be found – almost as may there are authors writing on competence-related matters. In the following, a selection of definitions by various authors will be compared (for a detailed discussion see Kouwenhoven 2003).

The basic structure of competence requires the following distinction:

- *The distinction between competence and performance.* Competence is the ability of a person to carry out a certain task (e.g., to have command of the German language). Performance is the implementation of a concrete subset of the task (e.g., to speak or to write German). A person's competence can be diagnosed only through his or her performance.
- *The distinction between competence as prescription and as ability.* Competence as prescription relates to a code or directive. Competence as ability describes what a particular person can actually do.

  Educational goals describe competencies as prescription or "prescriptive skills." Learning controls describe individual abilities or "personal skills."

  Opponents view the movement toward competency-based systems as reductionistic and prescriptive, especially in general education areas (Betts and Smith 1998).

- *The distinction between subject-specific skills and mental ability.* When one regards mental abilities as people's psychological dispositions to live, act, and behave (e.g., the ability to perceive, remember, or feel), then a professional role is not necessarily a mental ability. Mental abilities are relatively independent of the requirements of a particular technical field. Subject-specific skills, however, are mainly determined by the context and professional recommendations of the technical field in question. Considerations regarding the skills needed in a particular field describe prescriptive but not personal skills. Thus, a psychological investigation is not sufficient for the determination of a subject-specific skill or for the development of a theoretical competency model.

The clarification of competence in education using semantic, rational, psychological, and empirical task analysis.

If one accepts the definition above, which states that each competency is precisely described by specifying a set of tasks and the corresponding degrees of competence, then the determination of specialist skills is a problem of task analysis. It is useful to distinguish four types of task analysis: "semantic," "rational," "psychological," and "empirical" task analysis.

These four kinds of task analysis for determining competence have different functions and relate to each other. As the first step of determining competence, the semantic task analysis describes what is meant by a specific competency.

The rational task analysis and the psychological task analysis contain requirements of a process which is necessary for solving the tasks that describe the skills. As far as rational task analysis is concerned, these requirements are provided from the perspective of the respective fields. Psychological task analysis refers to additional assumptions of a specific person's psychological processes.

For reasons of field orientation, rational task analysis precedes psychological task analysis. During a stepwise clarification of competence, the results of the individual task analyses may reveal repercussions on the previous task analyses. For example, the result of an empirical task analysis may result in a correction of the psychological task analysis. The revision of the semantic and rational task analysis is, however, limited, since they are determined by the requirements of specific subject content.

Instructional psychology has a long tradition of assigning teaching materials to certain forms of learning, which shall not be discussed here in detail. The empirical task analysis finally determines what a person is actually doing when solving the tasks which represent the competence to solve a given problem (e.g., Schott and Azizi Ghanbari 2008, p. 62).

Important Scientific Research and Open Questions

The educational term competency-based learning is not the result of a fashion of introducing new words and concepts, but an objective phenomenon in education motivated by social and economic, political, and educational conditions. First of all, it is professional education's reaction to changes in social and economic demands and to the innovative processes which have appeared together with the global market economy (Lobanova and Shunin 2008). At the international level, work in the field of competencies began in 1990 under the aegis of the Organization of Economic Cooperation and Development (OECD) with the international interdisciplinary program DeSeCo (Definition and Selection of Competencies: theoretical and conceptual foundations).

The quality of subject-specific skills taught at all levels of education – secondary, higher, and continuing – plays a decisive role in establishing individual and national well-being. Good education depends inter alia on the quality of teaching itself, i.e., the methods used to convey the relevant educational material.

The two most important quality criteria for practical interventions both in education and in any other area of application are:

1. "the *relevance* of the objective of the respective intervention, its justification and desirability
2. the *efficiency* of the intervention. A[n] intervention is effective if:
   a. the desired effect or goal of the measure (i.e., output) is achieved in a sufficient manner. In education, this is mainly characterized by the intended learning results; is resource friendly. That is, the desired effect is achieved at a good cost-benefit ratio without harmful side effects." (Schott and Azizi Ghanbari 2010) (p. 481).

Efficiency is of fundamental importance to the (successful) teaching of specialized skills. A theoretical competence model that requires an unrealistic amount of time is without practical value. Relevance and efficiency of teaching measures are referred to as "quality of intervention."

The pathways of learning no longer lead automatically to traditional institutions of higher education. Instead, they lead most directly to learning opportunities in which competencies are defined explicitly and delivery options are multiple. This new paradigm will ultimately redefine the roles of faculties, institutions, and accreditation authorities.

Although cognitive skills and abilities gained through traditional higher education programs are the decisive results of education, the choice of competencies can still hardly be reduced to these frameworks only. This is just one aspect of the difficulty to be considered. As the theory and practice of hiring procedures for young specialists demonstrates, noncognitive aspects play an important role, such as practical skills, attitudes, motivation, value preferences, and ethics, which are not necessarily achieved and developed in the field of formal education. Furthermore, terms like competence, competency, key competences, and skills are often used ambiguously.

Cross-References

► Cognitive Learning
► Cognitive Tasks and Learning
► Subject of Learning

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Competitive Learning

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Definition

Competitive learning is a learning mechanism where the components of the learning systems compete for the executions of the learning procedures. As opposed to the noncompetitive learning algorithms, where in each learning step all of the components of the learning system take part in the learning procedure, in competitive learning algorithm only a part of the components that fulfill a predefined criterion win the right to execute the learning procedure. The competition between the components of the learning system usually results in the clear division of the training data or underlying dynamics of the learning target among the components.

Theoretical Background

Over the last several decades, a rich variety of competitive learning algorithms have been successfully proposed. In this article, three of the most popular competitive learning algorithms are explained in detail. All of the examples of competitive learning algorithms in this article were implemented with MATLAB.

K-Means

Due to its simplicity and clarity, K-means algorithm (Forgy 1965) (MacQueen 1967) is one of the most used competitive learning algorithms. Given N d-dimensional points $\{x_1, x_2, \cdots, x_N\}$, the purpose of K-means algorithm is to divide these data into K nonhierarchical clusters. Here, cluster i is represented by a prototype vector, $C_i \in R^d$, which is the centroid of a collection of vectors belonging to that cluster. These prototypes are randomly initialized or initialized according to some prior knowledge in the beginning of the learning process.

In K-means algorithm, the prototypes are competitively trained to minimize a cost function, traditionally E, defined in (1):

$$E = \sum_{i=1}^{K} \sum_{j=1}^{N} \alpha_{ij} ||C_i - x_j||^2 \quad (1)$$

Here, $\alpha_{ij} = 1$ when point j belongs to cluster i or otherwise $\alpha_{ij} = 0$.

In the learning process, when a point $x(t) \in \{x_1, x_2, \cdots, x_N\}$ is presented at time t, a winner prototype, $C_{w(x)}$, is competitively decided by calculating the distances between the presented point and all the prototypes as follows:

$$w(x) = arg \min_i ||x - C_i||^2 \quad (2)$$

The winner is then modified so that it moves toward the given input, while the other prototypes remain the same. The modification rule is formulated in (3) with η as the learning rate:

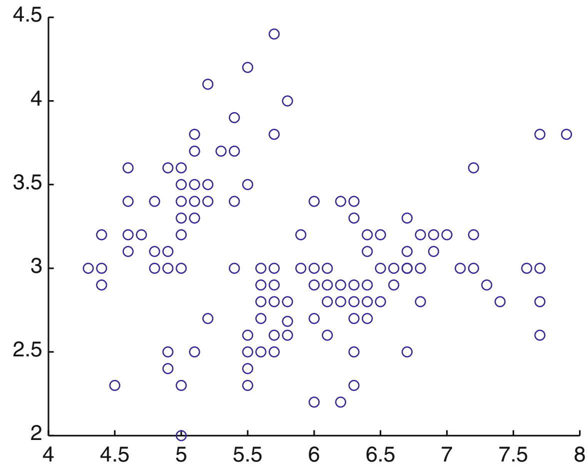
$$C_i(t+1) = \begin{cases} C_i(t) + \eta(\mathrm{x}(t) - C_i(t)) & i = w(x) \\ C_i(t) & i \neq w(x) \end{cases} \quad (3)$$

After the termination of the learning process, it is clear that a prototype, C_i is the approximation of the centroid of the points belonging to the i-th cluster, S_i, as follows:

$$C_i \approx \frac{1}{N_i} \sum_{x_j \in S_i} x_j \quad (4)$$

In (4), N_i is the number of points in the i-th cluster.

To give a better understanding on the clustering characteristics of K-means algorithm, in this article, this algorithm is applied to simplify Fisher's Iris data set (Fisher 1936). This data set originally contains four-dimensional points, but here for the purpose of clarity each point is represented by its first two elements. The distribution of these two-dimensional data is shown in Fig. 1. The Voronoi diagrams of K = 10 prototypes and K = 20 prototypes are shown in Figs. 2 and 3, respectively.

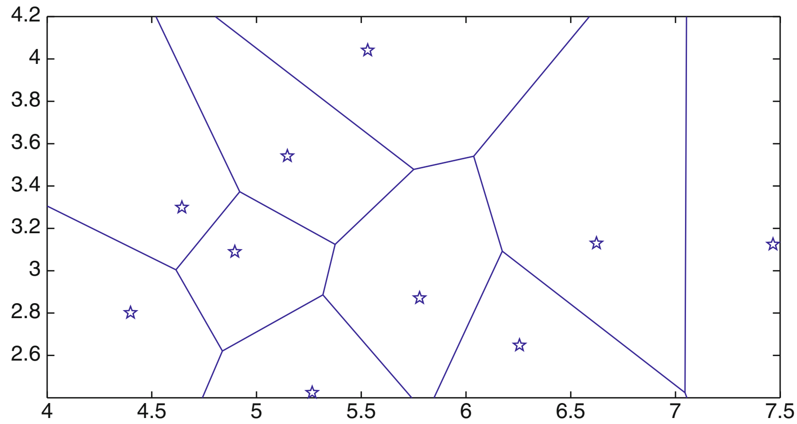


Competitive Learning. Fig. 1 Data

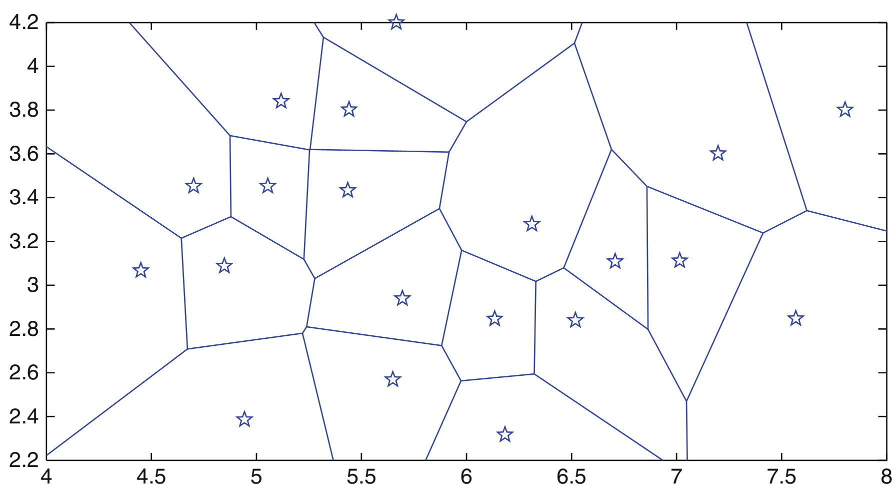
Self-organizing Map

K-means algorithm allows us to divide a multivariate data space into K clusters where each cluster is represented by a prototype vector. While this property is often useful for understanding the structure of the data, it is not possible to visualize these clusters for multivariate data. One of the motivations behind the introduction of self-organizing maps (SOM) (Kohonen 1982) is to map multidimensional data into a lower-dimensional space (usually two or one dimension) while keeping the topological characteristics of the data correct. The low-dimensional map can then be visualized for helping us to intuitively understand the structure of the multivariate data. The topology-preserving property of SOM is illustrated in Fig. 4, where the original dimension of the data (represented by Δ, ∇, and ★) is three. In their original dimension, two similar points, Δ and ∇, are positioned in each other's vicinity, while a dissimilar ★ is in the far end of the data space. In mapping data into a lower-dimensional space, SOM preserves the similarity characteristics of the data, such as that shown in Fig. 4 where Δ and ∇ which are similar in their original dimension are positioned close to each other in map, while ★ is diagonally positioned from these two points.

As illustrated in Fig. 5, the structure of SOM is supported by two layers, the input layer, where the external inputs are received, and the competitive layer, where the low-dimensional map is formed. The input layer of SOM contains the same number of neurons, d, as the dimension of the data, while the



Competitive Learning. Fig. 2 K = 10



Competitive Learning. Fig. 3 K = 20

competitive layer of SOM contains $N_x \times N_y$ neurons that are aligned in a two-dimensional grid. The i-th neuron in the competitive layer represents a prototype vector $C_i \in R^d$. Similar to K-means algorithm, this prototype C_i should be the reference for input vectors x that are similar to it. SOM ensures the topological correctness of the map by assigning similar prototypes to the neighboring neurons in the map.

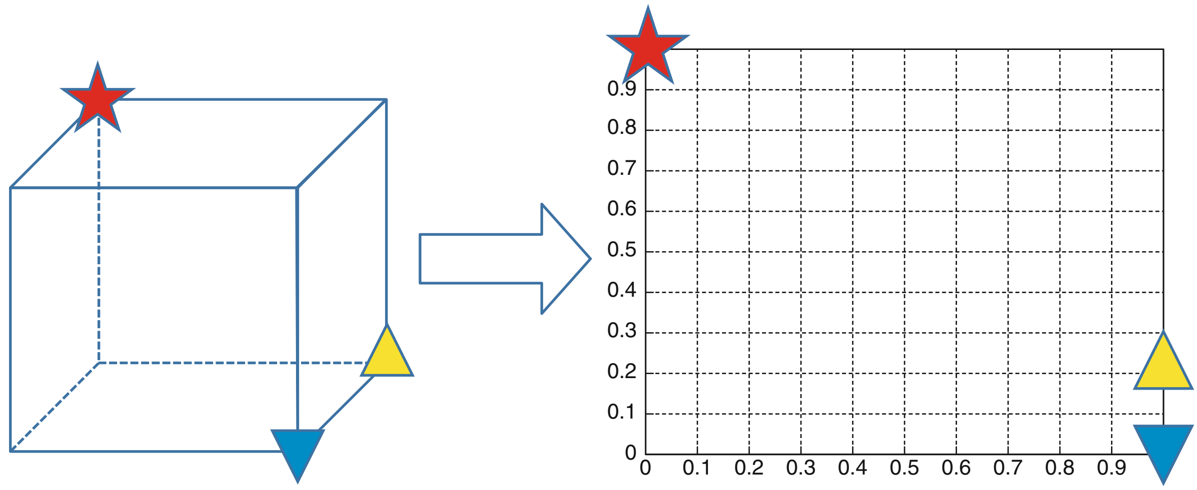
This topological-correctness is obtained through a competitive learning process, in which, when an input vector x is presented at time t, the neurons in the competitive layer compete to be the reference for this input by measuring the distance between their current prototype vectors with this input where. The most similar prototype input is then designated as the winner according to (5):

$$w(x(t)) = arg \min_i ||x(t) - C_i(t)||^2 \quad (5)$$

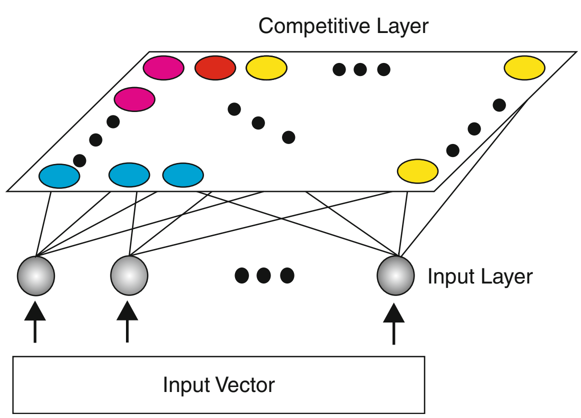
The winner and the neurons in its neighborhood are allowed to modify their prototypes as follows:

$$C_i(t+1) = C_i(t) + \eta(t)\text{dist}\,(i, w(x(t))) \times (x(t) - C_i(t)) \quad (6)$$

Here, $\eta(t)$ is a constantly decreasing function and dist(i,w) is the distance between the i-th neuron and the winner.



Competitive Learning. Fig. 4 Topology-preserving mapping



Competitive Learning. Fig. 5 Structure of SOM

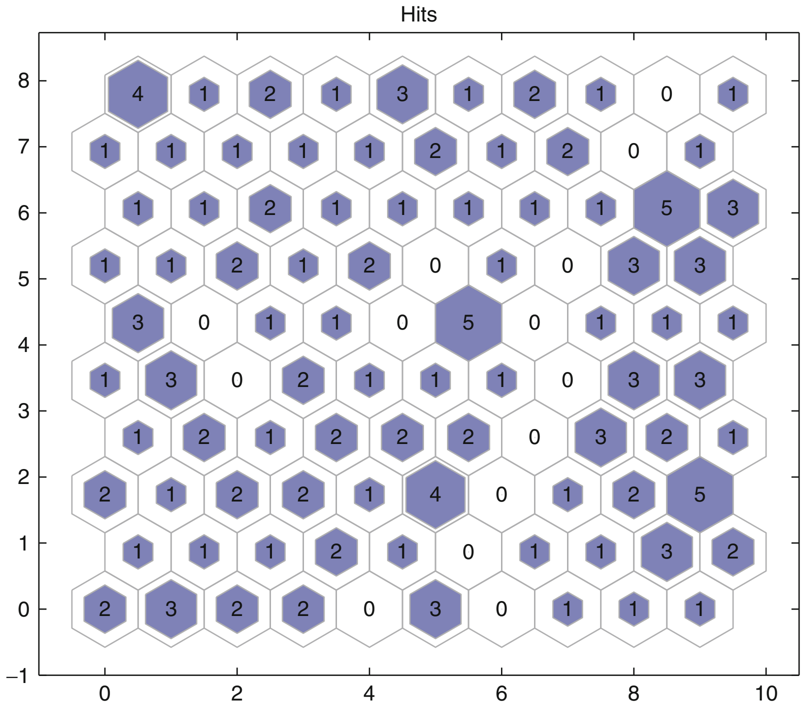
To give a clearer understanding on the topology-preserving mapping characteristics, SOM with 10 × 10 neurons is trained with the original 150 points of the four-dimensional Iris data (Fisher 1936) which naturally cannot be visualized on their original data space. The result is shown in Fig. 6, where the hexagons are the neurons in the map. The gray area of a hexagon is proportional to the number of inputs that refer the corresponding neuron as their prototype (also shown with a number inside the hexagon). Figure 7 explains the topological characteristics of this map. In this figure, neurons are represented as gray hexagons, while the colors of the areas connecting these hexagons indicate the similarities of the prototypes of the corresponding neurons, in which similar prototypes are connected with light color, while dissimilar prototypes are connected by dark color. From this figure, we can learn that most of the neighboring neurons represent similar prototypes and it is also obvious that the map is roughly divided into two parts by a string of dark areas, which can be regarded as a kind of border in the data space.

The simple example shows that the ability to visualize the multivariate data helps us in intuitively understanding the structure of the data.

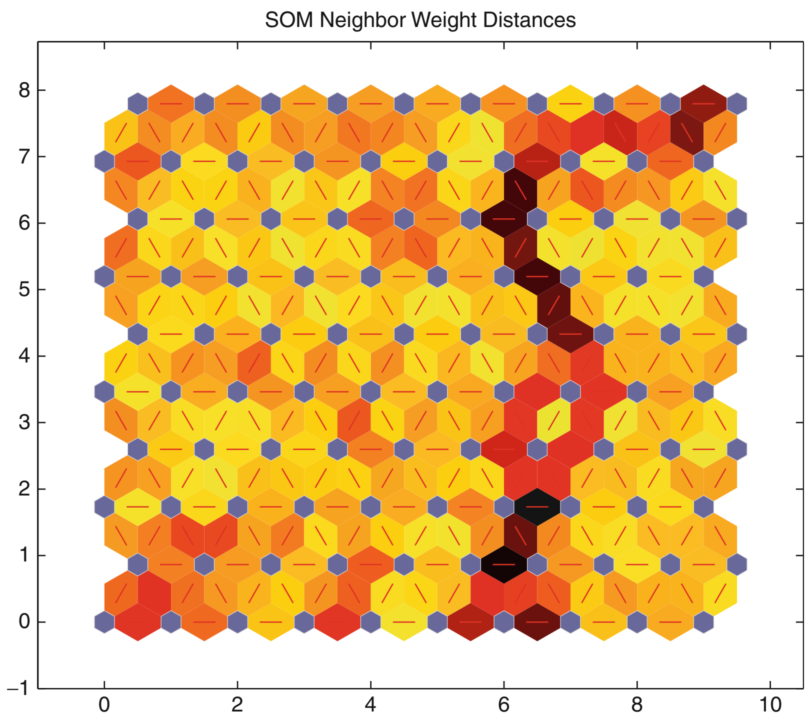
Learning Vector Quantization

Unlike K-means algorithm and SOM that quantize unlabeled data into a specified number of prototype vectors, learning vector quantization (LVQ) quantizes labeled data into a predefined number of labeled prototype vectors. Similar to K-means and SOM, the prototypes are generated through a competitive learning process, but taking the labels of the training data into account. After the learning process, the collections of the prototype vectors can be used for classifying unlabeled vector.

The training process in LVQ is started by initially setting K prototypes, usually by choosing K vectors from the labeled data. In the competitive training process for each presentation of a labeled vector x(t), a winner prototype $C_{w(x)}$ is chosen as K-means algorithm in (2). However, in LVQ the labels of the given vector x(t) and the winning prototype $C_{w(x)}$ play an important part in modifying the prototype as follows:



Competitive Learning. Fig. 6 SOM: iris data



Competitive Learning. Fig. 7 Topological relation

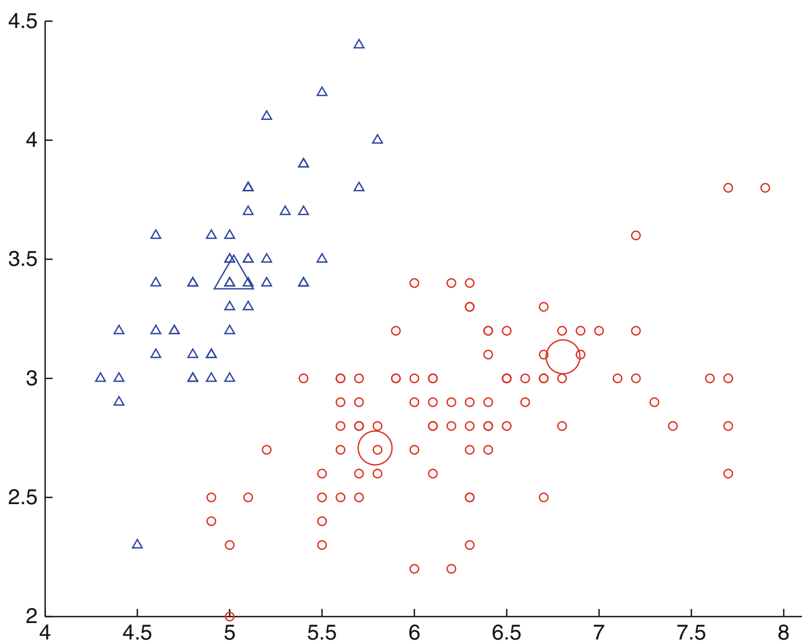
$$C_{w(x)}(t+1) = \begin{cases} C_{w(x)}(t) + \eta(\mathrm{x}(\mathrm{t}) - C_{w(x)}(t)) & l(C_{w(x)}(t)) = l(\mathrm{x}(\mathrm{t})) \\ C_{w(x)}(t) - \eta(\mathrm{x}(\mathrm{t}) - C_{w(x)}(t)) & l(C_{w(x)}(t)) \neq l(\mathrm{x}(\mathrm{t})) \end{cases} \quad (7)$$

It is obvious that with the modification rule in (7), a winner prototype with the same label as the input vector is pulled toward the vector while a winner prototype with different label is repelled away from the input vector. The non-winner prototype vectors remain unmodified. An example of LVQ is given with a simplified Iris data similar to that of K-means, except that the data are labeled. Originally the Iris data are labeled with three classes; however in this example for simplicity, the labels of data belonging to one class were kept, while the two other classes were merged and labeled as one new class. The distribution of the two-class data is shown in Figs. 8 and 9, where data belonging to one class are expressed with △s and the data from the other class are shown with ○s. In these figures the prototypes are shown with large △s and ○s. Figures 8 and 9 show the distribution of the prototypes when their numbers are three and six, respectively. It is clear that the prototypes are well positioned to quantize the data.

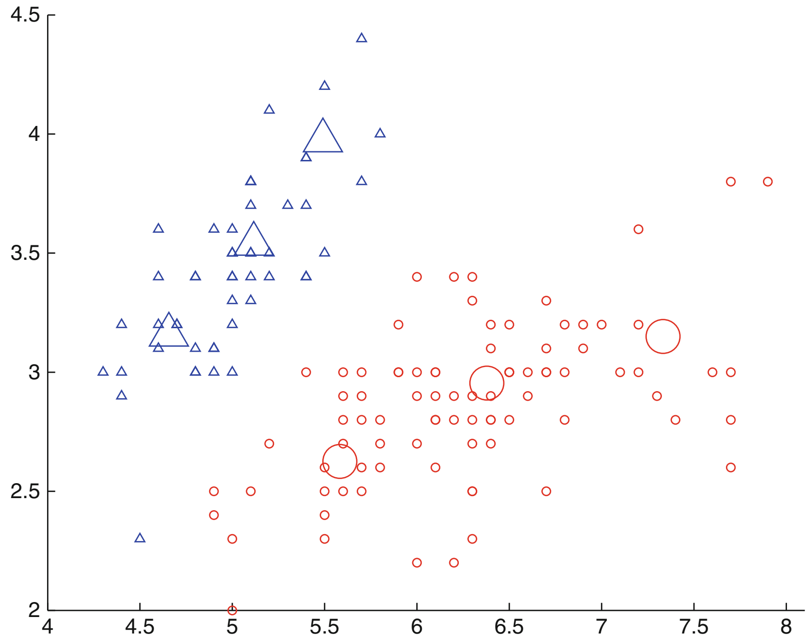
After the termination of the learning process, LVQ can be used for deciding the label of an unlabeled vector. In this case, when an unlabeled vector is presented, the vector is assigned the label of the most similar prototype. The competitive learning mechanism of LVQ is improved in LVQ2 and LVQ3 where the modifications of the prototype vectors are only executed when they are in the vicinity of the borders between different classes, which will generate better dividing hyperplane between different classes.

Important Scientific Research and Open Questions

Here three of the most utilized competitive learning algorithms are explained. However, over the recent decades, there are many interesting competitive learning mechanisms with various objectives and properties. Neural gas (NG) (Martinetz et al. 1993) is a kind of self-organizing algorithm similar to SOM; however the prototype vectors in NG are not bounded in grid neighborhoods. In NG, the similarity between neighbors is decided using the ranking of the Euclidean distances between the input vector and the prototype vectors. The most significant difference between SOM and NG is that in modifying the prototype vectors NG minimizes a global cost function which is not available for SOM. Modular network SOM (mnSOM) (Tokunaga and Furukawa 2009) was proposed to



Competitive Learning. Fig. 8 LVQ(k = 3)



Competitive Learning. Fig. 9 LVQ(k = 6)

expand the ability of SOM to self-organized different dynamics into low-dimensional maps that can be visualized.

Competitive Learning is also traditionally associated with Hebbian learning.

Cross-References

- ▶ Hebbian Learning
- ▶ Learning in Artificial Neural Networks
- ▶ Self-organized Learning
- ▶ Supervised Learning
- ▶ Unsupervised Learning

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Complex Action Learning

▶ Neurophysiological Correlates of Learning to Dance

Complex Communication

▶ Intelligent Communication in Animals

Complex Declarative Learning

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Synonyms

Knowledge acquisition

Definition

Declarative knowledge is knowledge about what the world is like. Examples include specific facts, e.g., that bananas grow on trees; general principles, e.g., that spring follows winter; and episodic information, e.g., that such-and-such a person was absent (or present) on a particular occasion. In epistemology, the term "knowledge" is used normatively to refer to assertions that are, in fact, true, but in the learning sciences, the term is used to refer to whatever assertions a person believes to be true.

Declarative knowledge contrasts with *practical knowledge* (also known as "competence," "expertise," "know-how," "procedural knowledge," and "skill"). Practical knowledge is knowledge about how to perform tasks such as tying one's shoelaces, using an electronic device, or proving an algebraic theorem. Practical knowledge is intrinsically related to goals and actions, while declarative knowledge (e.g., *the Earth is round*) is neutral with respect to purpose. Practical knowledge is primarily acquired via practice, while declarative knowledge is primarily acquired via observation and discourse. A popular belief holds that the two types of knowledge follow different forgetting curves, with declarative knowledge (e.g., the content of a text) fading faster than practical knowledge (e.g., the skill of riding a bicycle), but this belief is not grounded in research.

It is useful to distinguish between *episodic knowledge*, i.e., knowledge of particular events, and *conceptual knowledge*, i.e., knowledge of concepts, facts, and principles. Many episodic memories are *autobiographical*, i.e., they are memories of a person's own experiences. Memories for events in stories are episodic but not autobiographical, because the events happened to the protagonist of the story.

Theoretical Background

Declarative knowledge resides in long-term memory (LTM). There is no way to measure the total capacity of LTM directly. But the average educated adult in a Western nation has been estimated to know approximately 50,000 words, and hence approximately that many concepts. Each concept enters into more than one piece of knowledge. Furthermore, estimates of the number of knowledge units required for expert performance in a cognitive domain fall in the 10,000–100,000 range. Competent but not expert performance is likely to require fewer knowledge units, but an individual is typically competent in more than one domain (cooking, driving, gardening, etc.). The lower bound on the size of the declarative knowledge base of an adult must hence be on the order of a million knowledge units. There are no estimates of the upper bound.

There are three main models of LTM. In *the propositional model*, the unit of knowledge is the *proposition*, which is approximately the meaning of a declarative sentence. Propositions are linked by logical relations (e.g., *follows from*, *instance of*) and form *intuitive theories* (also known as *belief systems*). In *the schema model*, the unit of declarative knowledge is instead the *schema*, which consists of *slots* (also known as "roles"), which are linked by semantic relations (e.g., *instrument for*, *recipient of*). For example, a schema for a birthday party has slots for, at least, the person whose birthday it is, the host, the presents, the cake, and the guests. To create a memory of a birthday party, the slots are filled with the details of the particular event. Schemas are interconnected because a schema can fill a slot in another schema. In the *network model*, every concept (node) is linked to other concepts, and the links represent adjacency in time or space, causal relations, or semantic similarity. The propositional model emphasizes the organization of declarative knowledge by topic, the schema concept highlights the importance of abstraction, and the network model captures the interrelatedness of all declarative knowledge. Neither model explains all relevant phenomena.

Learning declarative knowledge involves at least three types of processes. First, the knowledge must be *acquired*. That is, it must be encoded into LTM; metaphorically, it is said to be stored in LTM. The acquisition process constructs new knowledge units. Second, the retention of knowledge in LTM is not perfect. Subjective experience suggests that knowledge *decays* over time, but there is less evidence for this than for *interference* among memory units. Third, using stored knowledge requires *retrieval*. Metaphorically, the retrieval process moves information from LTM into working memory (WM). The latter holds those knowledge units that are currently attended. There is consensus that the storage metaphor, albeit convenient and widely used, is misleading. It is more accurate to think of retrieval as the activation of a subset of LTM. Failure to recall can be due to failure to encode, imperfect retention, or failure to retrieve. When the learned knowledge is complex, these processes become complex as well.

Important Scientific Research and Open Questions

Acquisition

A significant proportion of the content of LTM consists of autobiographical information acquired in the course of everyday experience. The creation of autobiographical memories requires no intentional effort, but subjectively the process appears selective: Some experiences are remembered well and others poorly or not at all. A popular hypothesis holds that the probability of encoding a particular experience is proportional to how closely the person pays attention. The explanatory power of this principle is limited by the lack of a theory of degrees of attention. Another popular hypothesis holds that the probability of encoding is proportional to the emotional quality and intensity of the experience. The research evidence for the latter principle is mixed: Some studies have found better recall for emotionally intense events (also known as "flash bulb memories"), while others have not. The intriguing but implausible hypothesis that all experiences are stored in LTM is proposed from time to time but difficult to test.

Conceptual knowledge is typically acquired via discourse. Knowledge about abstractions (e.g., the gross national product, the square root of -2), the past (e.g., World War II), theoretical entities (e.g., chemical atoms), and other matters with which we have no firsthand experience is necessarily learned via some type of communication (discussing, listening, reading, watching, etc.).

The essence of the acquisition process is to relate the new information to previously acquired knowledge. Research on discourse comprehension, specifically, has revealed multiple knowledge-based processes, including *lexical disambiguation* (identifying the intended meanings for ambiguous words), *parsing* (identifying the relations between parts of a sentence), and *bridging inferences* that link the sentences in a text into a coherent whole. There is also evidence that the mental representation of a text undergoes successive transformations in the course of reading: The initial perception of the words and sentences – the *surface representation* – is transient and rapidly replaced by a representation of the meaning of the sentences and their relations to each other – the *text base* – which in turn generates a representation of the referent of the text – the *situation model.* The latter tends to be better retained than the first two. Each transformation draws upon the reader's prior knowledge. Differences in prior knowledge between author and reader probably accounts for a significant proportion of failures to learn from text.

The acquisition of declarative knowledge becomes even more complex when a discourse directly contradicts the learner's prior knowledge. This case is studied under the label *cognitive consistency* (also known as "cognitive dissonance") in social psychology and *conceptual change* in the learning sciences. Resistance to contradictory information is proverbial and easily observed in public discourse, but it also operates in reading and declarative learning generally. A variety of cognitive mechanisms have been proposed to explain resistance. These include doubting the veracity of the source, creating exceptions, and introducing new assumptions (also known as "abductive reasoning"). Evidence from both social psychology and the history of science supports the intuition that the degree of resistance is a function of the centrality of the contradicted belief. Resistance processes might cause new information to be distorted or misunderstood.

There is no widely accepted theory of how resistance to contradictory information is overcome. The idea that resistance can be removed by undermining prior conceptions with *anomalies* – counterarguments and demonstrations – has not been shown to improve the effectiveness of school learning. An alternative hypothesis holds that a misunderstanding is due to a misclassification of some phenomenon under the wrong ontological category, so successful acquisition requires an *ontological category shift.* A related proposal is that a phenomenon can be understood differently by *re-subsuming* it under a different intuitive theory. It is likely that there are multiple paths to new knowledge, each involving different processes.

Retention

Everyday experience shows that the longer the time since acquisition, the lower the probability of successful recall. Experimental studies have revealed that forgetting follows a negatively accelerate curve, i.e., forgetting is rapid immediately after acquisition but the rate of forgetting decreases over time. The mechanism that produces this regularity is not fully understood.

Complex declarative knowledge is also affected by processes that alter the content of memory. F. Bartlett proposed in the 1930s that the memory of a complex structure like a story undergoes a process of abstraction and compacting that leaves only the gist, typically embellished with a few striking details. Later, D. Ausubel proposed the related principle that memory for expository text looses in specificity over time and becomes absorbed into its overarching abstraction ("obliterative subsumption"). Also, there is strong evidence for both proactive and retroactive *interference* between successive acquisition processes. Researchers have found evidence that declarative knowledge is affected by repeated efforts to recall and use it. Each recall involves a certain amount of reconstruction to fill gaps in the stored information. The reconstructions are themselves stored and become part of the memory. Future retrievals may or may not distinguish between the original information and the subsequent reconstructions. The underlying cause of such effects might be lack of *source monitoring*, which causes pieces of information from different sources to be fused in memory.

Retrieval

Retrieval requires a *probe* (also known as "cue") that specifies the needed information. The source of the probe can be a question asked by someone else, a deliberate attempt to recall events in the environment or implicit task demands. The retrieval probe guides the search through LTM. Successful retrieval requires that the cognitive system makes contact between the probe and the sought after knowledge structure. Due to the size of the knowledge base and the probabilistic character of the retrieval process, the latter might fail to *access* a piece of knowledge even though it is, in fact, *available* (i.e., present) in LTM.

The probability of successful retrieval, given that the target information has been encoded and retained, is a function of multiple factors. These include the number of times a knowledge unit has been retrieved in the past and the time since the last retrieval. Coherent and interconnected knowledge structures provide more support for retrieval than isolated fragments. Consequently, individuals with large amounts of well-organized knowledge that is used frequently – experts – exhibit superior memory for knowledge that is relevant to their area of expertise.

The greater the similarity between the probe and the target representation in memory, the higher the probability of retrieval. This creates the problem of *transfer*, i.e., the application of knowledge acquired in one context (e.g., a classroom) in another, possibly dissimilar context (e.g., everyday life). Cognitive psychologists find less transfer than they expect in laboratory experiments, and educators lament that students' knowledge is "inert," i.e., not retrieved when needed. The possibility of retrieval, given an application context, depends on how the knowledge was encoded initially (*encoding specificity*). One way to increase the probability of retrieval is therefore to anticipate the future use of knowledge while it is acquired and encode it accordingly (*transfer appropriate processing*). When future use cannot be anticipated, transfer can be facilitated by encoding the information in multiple ways (*encoding variability*).

Related Areas

Research on the acquisition of declarative knowledge has generated novel instructional techniques. Research on knowledge distortion has proven useful in the evaluation of eyewitness reports and other topics in law and psychology. Social research on prejudice and stereotypes is closely related to, but not well integrated with research on knowledge acquisition in the learning sciences.

Cross-References

- ▶ Abductive Learning
- ▶ Advance Organizers
- ▶ Analogical Reasoning
- ▶ Ausubel, David P. (1918–2008)
- ▶ Belief Formation
- ▶ Categorical Learning
- ▶ Classification Learning
- ▶ Cognitive Dissonance in the Learning Process
- ▶ Conceptual Change
- ▶ Discourse and the Production of Knowledge
- ▶ Dogmatism and Learning
- ▶ Episodic Learning
- ▶ Fact Learning
- ▶ Meaningful Verbal Learning
- ▶ Schema-Based Learning
- ▶ Verbal Learning

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Complex Learning

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Synonyms

Integrative goals

Definition

A common complaint of students is that they experience the curriculum as a disconnected set of topics and courses, with implicit relationships between them and unclear relevance to their future profession. This complaint prompted the initial interest in complex learning. The term was introduced in the 1990s to refer to forms of learning aimed at ► integrative goals (Gagné and Merrill 1990). Learning goals that require the integration of multiple objectives are frequently encountered when instruction must reach beyond a single lesson or course, for example, when professional competencies or complex skills are taught. Complex learning takes a holistic rather than atomistic perspective on learning and teaching processes (van Merriënboer 2007). First, complex contents and tasks are not reduced into simpler elements up to a level where the single elements can be transferred to learners through presentation and/or practice, but they are taught from simple-to-complex *wholes* in such a way that relationships between elements are retained. Second, complex contents and tasks are not divided over different domains of learning, but knowledge, skills, and attitudes are developed simultaneously.

Theoretical Background

The concept of complex learning is rooted in holism (van Merriënboer 2007). The traditional atomistic approach in education reduces complex contents and tasks into simpler elements, until a level where the distinct elements can be transferred to learners through presentation and/or practice. The elements are thus taught as readymade pieces, which correspond to specific, single objectives. This approach works well if there are few interactions between the elements or associated objectives, but, according to the holistic perspective, it does not work well if objectives are interrelated to each other. For such integrative objectives, the whole is more than the sum of its parts. Holistic approaches basically try to deal with complexity without losing sight of the relationships between elements. They do so by teaching from simple to complex wholes. Right from the start, learners are confronted with the most important relationships between the elements of complex tasks or complex information.

Another characteristic of the atomistic approach in education is that skills, knowledge, and attitudes are often taught separately. For example, knowledge is taught in lectures, skills are taught in a skills lab, and attitudes are taught in role plays. This approach makes it difficult if not impossible for learners to integrate objectives from different domains of learning. Characteristic of complex learning is that integrative objectives are assumed to be rooted in different domains of learning, including the declarative or conceptual domain, the procedural or skills domain (including perceptual and psychomotor skills), and the affective or attitudes domain. It thus refers to the simultaneous occurrence of knowledge construction, skill acquisition, and attitude formation.

Important Scientific Research and Open Questions

The main research question is how complex learning could best be evoked and supported. Most educational theories assume that complex learning occurs in situations where learning is driven by rich, meaningful tasks, which are typically based on real-life, professional tasks. Such tasks are called learning tasks (van Merriënboer and Kirschner 2007), enterprises (Gagné and Merrill 1990), scenarios, projects, or problems. Well-designed learning tasks explicitly aim at integrative objectives, by forcing learners both to coordinate different aspects of task performance and to integrate knowledge, skills, and attitudes. Guidance is necessary to help learners deal with the complexity of tasks, that is, to provide supports that enable them to deal with more complex content and skill demands than they could otherwise handle. Moreover, provided guidance and support should gradually decrease in a process of "scaffolding," as learners gain more expertise (e.g., Reiser 2004). ► Cognitive load theory (van Merriënboer and Sweller 2005) explicitly studies methods that might help to reduce the high cognitive load that is imposed by rich learning tasks. Van Merriënboer et al. (2003), for example, describe on the basis of ► four-component instructional design methods that might help reduce high cognitive load: (a) simple-to-complex sequencing of classes of equally difficult whole tasks, (b) working from worked examples to conventional problems, (c) just-in-time presentation of helpful information, and (d) provision of part-task practice for routine aspects of tasks.

With regard to learning outcomes, complex learning explicitly aims at ► transfer of learning, that is, the ability to apply what has been learned to unfamiliar problems and/or in new situations. The main assumption is that complex learning yields a highly integrated knowledge base, organized in cognitive schemas, which facilitates transfer (Gagné and Merrill 1990). On the one hand, particular types of learning tasks (e.g., goal-free problems, worked examples, completion tasks), which are carefully tuned to the current level of expertise of learners, contribute to the development of an integrated knowledge base and subsequent transfer performance; on the other hand, ► variability of practice should ensure that the whole set of learning tasks varies on all dimensions on which tasks also differ from each other in the real world, including surface features and structural features, to reach transfer (for an overview, see van Merriënboer and Sweller 2005).

Cross-References

- ► Cognitive Load Theory
- ► Four-Component Instructional Design
- ► Transfer of Learning
- ► Variability of Practice

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Complex Problem Solving

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Synonyms

Dealing with uncertainty; Dynamic decision making; Problem solving in dynamic microworlds

Definition

Complex problem solving takes place for reducing the barrier between a given start state and an intended goal state with the help of cognitive activities and behavior. Start state, intended goal state, and barriers prove complexity, change dynamically over time, and can be partially intransparent. In contrast to solving simple problems, with complex problems at the beginning of a problem solution the exact features of the start state, of the intended goal state, and of the barriers are unknown. Complex problem solving expects the efficient interaction between the problem-solving person and situational conditions that depend on the task. It demands the use of cognitive, emotional, and social resources as well as knowledge (see Frensch and Funke 1995).

Theoretical Background

Since 1975 there has been started a new movement in the psychology of thinking that is engaged in complex problems in contrast to simple problems. Essential impulses for this development came from external, shocking events like the oil crisis or the first analyses of the "Club of Rome" at that time, which showed the constraints of growth and which made humanity-threatening problem fields visible. Besides that, the dissatisfaction about the nonpredictability of relevant characteristics like professional, economical, or political success based on classical intelligence tests led to a search of alternative measurements for the assessment of the way humans deal with complex situations, a search for "operative intelligence," as it was coined by Dietrich Dörner.

As an alternative, the use of computer-simulated scenarios was proposed. Such "microworlds" allow experimental research of complex problems under controlled conditions (Brehmer and Dörner 1993). For example, the scenario "Lohhausen" (Dörner 1997) simulated the events in a fictitious village. The subject had to act as the mayor of a small city for simulated 10 years (essentially reduced to nearly 10 h of gaming time) and had to care about the well-being of the community and its financial wealth. For this task, the fictitious mayor could control the events and shape the town according to her or his visions. Based on the data from successful and less successful subjects in this scenario, interesting hypotheses about the conditions of success and failure in dealing with uncertainty and complexity have been formulated.

Since that early start of this research program with "Lohhausen" in the mid-1970s, numerous scenarios with varying extent and from different domains (e.g., economy, ecology, policy, technology) have been developed and applied in both basic and applied research. In the following sections, I will outline characteristics of complex problems, describe tendencies in research, illustrate empirical results, and discuss problems and perspectives of this approach.

Characteristics of complex problems considerably differ from requirements of simple problems. Five features have been differentiated traditionally (Funke 2003):

1. *Complexity of the problem situation.* Traditionally, complexity is defined based on the number of variables in the given system. Surely, this is only a first orientation for the estimation of problem difficulty, but additional characteristics permit more reliable assertions. Complexity demands from the problem solver a simplification through reduction to the essential.
2. *Connectivity between involved variables.* Needless to say, it is not the pure number of variables that is decisive for the workload on the problem-solving person, but the connectivity between these. Assuming that in a system of 100 variables every variable is connected to only exactly one other, the connectivity is lower than in a system in which *all* variables are connected to each other. For making mutual dependencies understandable, a model of the connectivity is required from the problem solver.
3. *Dynamics of the situation.* This feature explains the fact that interventions into a complex, networked system might activate processes whose impact was possibly not intended. A unique variant is the own (intern) dynamic ("eigen-dynamics"). It signifies that in a lot of cases the problem does not wait for the problem-solving person and his/her decisions, but the situation changes itself over time. Dynamic requires from the problem solver the consideration of the factor "time."
4. *Intransparency* concerning the variables involved and concerning the definition of the goal. In an intransparent situation, not all required information about variables and possible goals are given. Intransparency requires from the problem solver the active acquisition of information.
5. *Polytely.* In a complex situation, reaching goals can be complicated. Usually there is more than *one* goal in a complex situation that has to be considered. Conflicts due to antagonistic goals require the forming of compromises and the definition of priorities.

Two approaches concerning research with complex problems differentiate with respect to procedures and to goals:

- The *experimental approach*: "Systematic manipulation of scenarios." Essential features of this approach are the experimental manipulation of the stimuli (the complex systems) and its condition of presentation. Particularly the systematic manipulation of scenarios (or system features) became a characteristic of this approach: degree of connectivity, presence or absence of eigen-dynamics, or the degree of time delays show influences on knowledge acquisition (= identification of systems) and knowledge application (= control of systems).

- The *correlational approach*: "Search for interindividual differences." Essential features of this approach are the search for interindividual differences and the search for correlations of success and failure. Systems attributes were kept constant to see the space of behavioral possibilities. Additionally, individual trajectories through complex systems were analyzed and correlated with constructs like test intelligence, personality characteristics, and so on.

Important Scientific Research and Open Questions

Many empirical results for solving complex problems are reviewed by Funke (2003) in detail. Here, only selected but important results are presented. They are ordered by their focus.

With respect to *Personality Aspects*, general intelligence measured by tests seemed to be an inappropriate predictor for handling complex problems according to previous research. However, by today's knowledge it seems clear that specific components of intelligence (like processing capacity) are predictive for the successful handling of complex problems (Wenke et al. 2005). Besides that, there are several forms of knowledge (e.g., system knowledge, control knowledge, strategic knowledge) that have to be taken into account.

The role of motivational parameters becomes apparent in the fact that problems which are considered as more important get more attention (e.g., the different handling of a simulated epidemic situation based on deadly smallpox or innocuous influenza). As a consequence, there are changes in strategies of information processing. If really high-stake problems are dealt with, the search for risk-defusing operators increases.

Emotional effects find expression, for example, in "emergency reactions" of the cognitive system. After perceived failure of problem solving a decrease in intellectual level follows, which is accompanied by a tendency for fast acting and for degenerated hypothesis generation. Also, the emotion regulation during complex problem solving plays an important role. Experiments showed that complex problem-solving situations with negative feedback of results lead to a higher information retrieval and to a better performance.

With respect to *Situational Aspects*, according to early studies, transparency of a system leads to easier information processing and increasing efficacy of intelligence concerning the success of problem solving. However, this moderator function of transparency is questioned repeatedly by current research.

Passive observing of a system or active intervention are two situational requirements, which lead to different acquirements. While pure observing delivers structural knowledge about the problematic system, control knowledge arises out of intervention conditions (Osman 2010). An increase in training also leads to improvement under complex conditions. However, there are certain conditions (e.g., existence of time delays), which do not profit from it.

The semantic appearance of a system is very important, since several prior knowledge structures are activated and can be used. However, prior knowledge is not always beneficial, especially if activated prior knowledge fitting only on the surface does not correspond to deeper structures.

With respect to *System Aspects*, the type of feedback is important for the success in solving the problem. Generally one can say: the more indirect and delayed a feedback for a certain condition of the system, the more difficult the controlled intervention. Formal features of systems also have proven their influential status concerning identification (knowledge acquisition) and controlling (knowledge implementation) within the process of complex problem solving (for a review, see Osman 2010).

Problems within complex problem-solving research deal with the following issues:

- *Identifying the quality of solution.* A decision about the quality of simple problem solving is easily possible, because the criteria for success are transparent. For complex problems the situation is different, because mostly there are no obvious goal conditions. A one-dimensional evaluation is not possible in that case. Problems arise if success of handling complex problems is used for diagnostic statements about the acting person.
- *Context effects.* One of the most impressive abilities of human cognition is its enormous context sensitivity. Structural similar tasks are treated differently in different semantic contexts. Different contexts also become apparent in processing the same

requirements in different cultures. Cultural comparison does not mean changing between nations or continents, but could happen simply on the level of "subcultures." Assessing how variations in context lead to variation in strategies and subjectively constructed problem spaces within the process of problem solving might be an important task of future research.

- *Training and the question of domain specificity or generalizability.* The question of domain specificity of problem-solving activities is closely related to the issue of context sensitivity. In case of research in complex problem solving, the question is one of transfer of knowledge and strategies between specific scenarios. It is generally accepted that confrontation with different scenarios leads to an extension of the realm of experience – however, there are no empirical evidences. The simple repetition of processing the same scenario leads to learning effects, but training itself means more: the acquisition of strategic competences universally applicable. Finding rules for unpredictable situations could be the squaring of a circle. Concerning application aspects, there is a huge challenge of psychological research in problem solving.
- *Missing theory.* The major problem of current research is the lack of a firm theory about dealing with complex problems. It is not even clear if there is a need for another theory besides a theory for solving simple problems. Indeed a global theory of cognition that describes and explains dealing with *all* forms of problems is needed. But such a "unified theory of cognition" (Alan Newell) does not seem to appear on the horizon.

Perspectives. Within the major area called "psychology of thinking and reasoning," the exploration of complex problems represents a question that is of great significance beyond our discipline. Thereby, a chance appears to devote psychology on a basis of verified findings to a field of application within areas like politics and business consulting ("give psychology a-way"). For this reason, more intensive data pooling and the refinement of appropriate theoretical approaches are needed. Interesting developments could be expected in following areas:

- *Task and requirement analysis.* It seems profitable to undergo an analysis of requirements concerning the tasks set by the different scenarios. Thereby, one would get from blanket description to precise testimonies. Scenarios have to be analyzed in form and content. It has to be explained properly what is measured.
- *Characteristics of the problem-solving process.* Once the requirements are known, cognitive processes within the acting person can be focused in detail. Particularly the differentiation between implicit and explicit processes and their relation to the distinction between novice and expert problem solving could be of peculiar interest. Based on this research, training procedures could be designed. Existing dynamic scenarios contributed to this purpose already because of their differentiation between different forms of knowledge, of strategies, and of metacognition.
- *Heuristics.* It seems promising to transfer our knowledge about heuristics found in research on decision making to the field of complex problem solving. Possibly simple heuristics control the processing of complex problems, an idea which would be helpful for finding a global theory.

Cross-References

► Complex Problem Solving
► Learning and Thinking
► Problem Solving
► Simulation and Learning: The Role of Mental Models
► Simulation-Based Learning

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Complex Psychology and Learning

► Analytical Psychology and Learning

Complex Tasks

► Cognitive Tasks and Learning

Composition Learning in Music Education

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Synonyms

Creative Thinking in Music; Creativity; Creativity in Music; Music Creation

Definition

Composition learning in music education refers to the result of creative thinking in music that takes shape in a process of bringing a musical product into existence by an individual or group of composers. Composition learning has specific meaning for the composer. Composition work takes the form of either notated music and/or audio recording. Composition learning in music education has traditionally held a secondary status to performance learning in music education curricula around the world.

Theoretical Background

J. Paul Guilford is known for being a pioneer in the study of general creativity. His speech to the American Psychological Association in 1950 marks the beginning of the study of general creativity in the United States. Psychological researchers then took up the following approaches to the study of creativity: psychometric, experimental, biographical, psychodynamic, biological, computational, and contextual. These approaches, particularly the psychometric, experimental, and contextual approaches, were used for much of the remainder of the twentieth century. Descriptive approaches to the study of creativity are now becoming more popular, as well as studies that place musical creativity in the context that it is intended to be used in practice. Where previous research placed more of a value on understanding the people, processes, and products of musical creativity, researchers now seem to be choosing to examine how confidence, peer-interaction, motivation, and self-efficacy interact with composition learning. Another strand of research is emerging that focuses on teachers as creative music makers.

Important Scientific Research and Open Questions

Research in the area of music teaching and learning has been focused primarily on music performance for much of the twentieth century. From about 1950 on, small pockets of researchers began the study of composition learning in the context of music education. While some countries – most notably England, Australia, and Finland – have adopted composition as a regular part of the music curriculum, composition as a major facet of the teaching and learning of music in the United States has been far less common. The following sections describe the most notable research efforts.

What Children Compose

Pioneering research on children's original music appeared in a series of monographs published in the 1940s by Gladys Moorhead and Donald Pond. These studies examined the musical characteristics of vocal and instrumental music created by children in an unstructured setting. Their research found that even the youngest school-aged children make use of simple melodic and rhythmic patterns in their compositions. Later research by John Kratus looked at the characteristics of music composed by children aged 5–13 in a more structured context. He found that between the ages of 5 and 11 there is steadily increasing use of melodic development, rhythmic patterns, tonal organization, and metric organization, suggesting a greater awareness and application of musical syntax as children age through the elementary years. Keith Swanwick and June Tillman used their analysis of music composed by children in elementary and secondary school to support a theoretical sequence of musical development, leading toward increasingly sophisticated use of materials, expression, form, and values. Other researchers have studied children's use of invented or standard notation in their compositions, examining the visual representation of music rather than the music itself. The growing body of research on children's compositions provides evidence that nearly all children are capable of composing music, just as nearly all children are able to draw, paint, act, and dance.

How Children Compose

Research on how children compose examines the thinking and actions children engage in during the act of composing. The study of these compositional processes is fraught with methodological difficulties because, unlike in the study of children's composed products, there is no created artifact to analyze. Instead researchers must infer mental processes based on the actions, interactions, and verbalizations of children engaged in an ambiguous task for which there is no correct answer. In a quantitative study of compositional processes, Kratus found significant differences in the ways 7-, 9-, and 11-year-old children used exploration, development, and repetition of musical ideas as they composed. He observed that the 11-year-olds in his study spent a greater amount of time developing and repeating musical ideas and less time exploring new ideas than did 7-year-olds. Much of the research on how children compose has been of a qualitative nature and has focused on small group composition in classroom settings. The emphasis of this research has been primarily on the social interactions among students (e.g., friendship) engaged in an assigned creative task, rather than on musical thinking and decision making. Results of this line of research suggest that children rarely develop their musical ideas when engaged in small-group classroom activities, and children are more effective composers when they are friends with others in their group. Two promising areas of research on compositional processes are (a) the use of the internet for collaborative composition, and (b) group composition and arranging in the context of garage bands.

Establishing an Environment for Composition

Composition learning in music education does not occur in a vacuum, for it is in classrooms, in teaching and learning situations that composition must occur for it to be a part of the school curriculum. Pamela Burnard suggests that various social structures, including society, out-of-school contexts, in-school contexts, and culture, interact to influence composition learning in the setting of music teaching and learning. Researchers such as Margaret Barrett have described music composition as an interaction between "freedom" and "constraint." This distinction might be a way of framing composition pedagogy as restrictions are placed on the task of composing as a way of channeling student creative work. Other researchers have examined the nature of feedback in aiding student compositions and the idea of helping students find their voice in their compositions.

Teachers' Attitudes Toward Teaching Composition

Work in this area of the literature could not have been done, had music education researchers not first invested time and effort in order to understand the composition processes and products of children. Their work has now paved the way for researchers to examine contextual factors that can impact the implementation of composition learning experiences in school settings. It is important that teachers first recognize that music composition is an essential area of musical learning, one that merits inclusion in the curriculum, for it to be adopted more widely in schools. Recent work suggests that preservice teachers in the United States plan to teach composition to a lesser extent than their English and Welsh peers. Differences have been attributed to the lesser status of composition as a curricular subject within the music education system in the United States. Teachers are socialized, by way of their experiences being a part of music education in their particular setting, to value and discredit certain aspects of teachable music experience in favor of other such experience. Researchers are doing work in this area in hopes of redefining and expanding upon the traditionally held view of the music teacher. This line of research seeks to better understand teachers' attitudes toward teaching composition as one of the missing links to composition's inclusion as a major curricular area within music education.

Assessment

Researchers have considered how to assess composition work. Generally speaking, the study of the assessment of creativity started in the 1950s with J.P. Guilford. E. Paul Torrance built on this work by devising standardized tests of creativity. Peter Webster then took the knowledge gained from the work of these researchers and developed the *Measurement of Creative Thinking in Music*. The MCTM is likely the most widely used assessment tool for measuring creative thinking in music.

Regarding composition learning in music education specifically, assessment has been a more frequent topic of discussion in the United Kingdom than in the United States. Researchers in England have been working on sophisticated rubrics to help teachers rate the composition work of students at all of the key stages. Researchers such as Teresa Amabile and Maud Hickey have taken up the task of developing ways of assessing student musical compositions.

Cross-References

► Cognitive Psychology of Music Learning
► Developmental Psychology of Music

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Composition of Groups

► Cooperative Learning Groups and Streaming

Composition of Learning Groups

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Synonyms

Average group level; Group configuration; Group homogeneity; Group heterogeneity; Group mix

Definition

The composition of a learning group refers to how a group of learners is composed. The learning group can refer to the school (school student body), a class group (class composition), or to the more flexible grouping of students within a class (within class grouping). The term *group composition* is used in the sciences of learning and cognition to refer to the characteristics of the group in terms of ability, achievement level, gender, ethnicity, age, etc. The group can be described from two main perspectives: the average level of the group and the heterogeneity (mix) of the group. The group-level variables are calculated by aggregating the background characteristics of all individuals in the group to an average (level) or a measure of heterogeneity (e.g., standard deviation). When both perspectives are combined, three types of groups emerge: homogeneous weak groups, homogeneous strong groups, and heterogeneous groups. The gender composition of learning groups, for example, has three main categories: two types of single-sex groups (all boys' groups, all girls' groups) and coeducational groups. Studies on *tracking* and *ability grouping* address the effects of grouping and mixing students by ability. Studies on multigrade and multiage classes address the effects of grouping and mixing students by age.

The *group composition effect* (sometimes called contextual effect) refers to the effect of the group-level variable (level or heterogeneity) on learners' outcomes over and above the effect of the individual-level variable. Group composition influences both academic and nonacademic outcomes.

One of the best-known group composition effects is the *big-fish-little-pond effect* (BFLPE) (Marsh et al. 2001). This effect indicates that equally able students have a lower academic self-concept when placed in a group with a higher average achievement level. It is beneficial for students' academic self-concept to be part of a group with a low average achievement level.

Theoretical Background

It has been widely established that the learning outcomes of an individual are not only affected by his/her individual background characteristics (age, gender, general ability, socioeconomic status, achievement level, etc.), but also by the composition of the group in which the learning takes place.

Class composition practices originated as an answer to the diversity in students' instructional needs. In homogeneous classes, teachers can better adjust their materials, level, and pace of instruction to the needs and interests of individual students (Hattie 2002). However, opponents claim that homogeneous grouping denies students to learn from peers of other ability, sex, ethnicity, social class, and/or age. Furthermore, lower tracks often get stigmatized, which leads to teachers not wanting to teach lower-ability tracks and lower-track students feeling discouraged (Hattie 2002).

The majority of the studies on group composition effects have found that it is generally beneficial for all students' achievement to be part of a group with a high average level. This also means that heterogeneous groups are generally beneficial for weak students' achievement and that homogeneous groups are best for strong students. However, heterogeneous grouping is generally considered as the best grouping practice in most cases, since the benefits for weaker students tend to be larger than the disadvantages for the stronger students. High-ability students tend to do well in either type of group. However, the range of abilities within the group should not be too wide, to increase productive interaction in cooperative small groups (Wilkinson and Fung 2002).

With regard to the students' academic self-concept, the grouping advice is exactly the opposite (see BFLPE). High-ability students have a higher academic self-concept in heterogeneous classes; while for low-ability students, it is better to be grouped in homogeneous classes.

Two main *explanations* have been put forward with regard to group composition effects: sociopsychological processes and instructional processes.

The sociopsychological processes of group learning (peer influences) refer to the normative and comparative processes in and between groups. The composition affects the group's norms about effort and investment in learning. The group rewards or punishes individuals for conformity or deviant behavior. Classes with an advantaged group composition develop a pro-academic culture in which academic achievement is highly valued, thereby stimulating everyone in the group to achieve. In disadvantaged groups, nonconformity with academic objectives and alienation from school are often rewarded.

The group can also be a comparative reference group, constituting a frame of reference against which the student evaluates his/her own accomplishments. According to his/her perceived position, the student develops feelings of relative deprivation or gratification that may affect his/her feelings and behavior. This is also called the "frog–pond effect": the student compares himself (size of the frog) to his/her fellow students (size of the pond). There is empirical evidence for comparative effects on the self-image, but not on achievement.

Students compare themselves not only to the others in their group, but comparisons are also made across groups. Interclass comparisons produce labels, and these collective labels influence expectations of teachers, peers, and parents. This process may stigmatize groups with an unfavorable group composition and activate a self-fulfilling prophecy of failure. Through group identification and assimilation, the labels also affect students' self-concept and expectations.

The second main explanation of the group composition effect is the *instructional process*. Advantaged groups tend to show less disciplinary problems, more higher-order questions, a broader curriculum, etc. In lower-ability groups, there is a more limited academic focus and a reduced opportunity to learn. Talented and motivated teachers are often teaching advantaged groups while low-ability classes are assigned to the least well-prepared teachers. However, these are correlations between group composition and instructional practices, making it difficult to disentangle composition and instruction effects. They can have separate and joint effects on student outcomes.

Moreover, Wilkinson and Fung (2002) argue that peer influences interact with instructional processes to mediate the effects of group composition on students' learning.

Important Scientific Research and Open Questions

The estimation of the effects of group composition on individual outcomes has greatly benefited from statistical advantages in the past decades. Especially *multilevel modeling* (also called hierarchical linear modeling) has improved correct estimations of the group composition effect, because this statistical method takes into account the nesting of learners in groups.

The composition of learning groups is studied in correlational studies, randomized controlled trials, and matched experiments (Slavin 1990). But there remains a lack of understanding on what happens in groups and how the group composition affects learning. A lot of work still has to be done to fully grasp the ways in which groups influence the individuals in the group. Some researchers also see the group composition as a phantom effect, an artifact of measurement error, or resulting from a failure to correct for individual differences.

One of the avenues for a better understanding of group composition effects, is through the study of *differential effects*. These differential effects essentially mean a cross-level interaction between the group variable and the individual variable. Such an interaction indicates that the group composition might have another effect on different types of students. For example, girls show higher math achievement in single-sex classes, whereas boys show higher achievement in coeducational classes.

Cross-References

▶ Ability Grouping (and Effects) on Learning

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Composition Writing

▶ Learning to Write

Comprehending

▶ Reading and Learning

Comprehension

▶ Receptive Learning

Comprehension Disorder

▶ Language-Based Learning Disabilities

C

Comprehension Monitoring

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Synonyms

Calibration of comprehension; Metacognitive monitoring; Metacomprehension; Metamemory for text; Self-regulated comprehension

Definition

The definition of comprehension monitoring has varied between two camps. In one, comprehension monitoring is defined as a metacognitive process that includes both the evaluation and regulation of understanding derived from discourse, in other words, verbal communication or the reading of text (see Hacker 1994 for a review of the early literature on comprehension monitoring). Evaluation requires a person to monitor and judge the degree to which understanding is successfully proceeding or has been successfully completed. Regulation requires a person to exert control to resolve problems and ultimately increase understanding. In the other camp, comprehension monitoring is restricted to the evaluation of understanding, and regulation is considered as a separate and unique process. The distinction between evaluation and regulation likely developed, in part, as a consequence of research in the field of metacognition, in which metacognition has been conceptualized as consisting of both a monitoring and control process (Nelson and Narens 1990). Although in application, the monitoring of comprehension is distinct from and yet interwoven with the control processes involved (Hacker 1998). In both camps, the definition of comprehension monitoring and the focus of research changed from the study of discourse, including verbal communication (e.g., Markman 1977), to examine primarily the reading of text. Our discussion will focus on the reading of text because the vast majority of studies have done so.

Comprehension monitoring is also referred to as "calibration of comprehension," "metacognitive monitoring," or "metacomprehension" (e.g., Maki and Berry 1984). The process of monitoring can be an implicit process that proceeds automatically during reading, or it can be an explicit process that proceeds intentionally with the reader employing comprehension monitoring strategies, such as questioning, clarifying, or summarizing, or with the reader making different types of metacognitive judgments. Most studies of comprehension monitoring have used (a) judgments of comprehension that measure the degree of understanding a text, (b) judgments of learning that measure the degree of understanding combined with the potential for successful recall at a later time, or (c) posttest judgments that reflect the degree of confidence in specific answers retrieved from memory (Maki et al. 2005; Nelson and Narens 1990). Other types of metacognitive judgments that have received less attention in metacomprehension research are ease-of-learning judgments and feeling-of-knowing judgments.

On the one hand, the term comprehension monitoring is something of a misnomer in that only part of the process is identified (Hacker 1998), with the regulation or control aspect sometimes included and sometimes not. On the other hand, the term metacomprehension has remained relatively consistent in the literature and refers mainly to monitoring, with control treated as a separate process from monitoring. For example, people could be very effective at monitoring their comprehension during reading but fail to exert control over their reading when comprehension failures are encountered. However, the model of metacognition proposed by Nelson and Narens (1990) has control processes intimately tied to monitoring processes, and these processes "must be considered as a system of interacting thought processes and not as a collection of independent parts" (Hacker 1998, p. 169). For this reason and because comprehension monitoring and metacomprehension recently have been studied largely in the context of self-regulated learning, we suggest that the components of monitoring and control should be integrated into the term self-regulated comprehension (Dunlosky et al. 2002; Hacker 1998).

Theoretical Background

Ellen Markman's work (e.g., 1977) was some of the first to examine how people monitor their comprehension. In her work with children, she used the error-detection paradigm in which inconsistencies were deliberately implanted in verbal instructions, and children were asked to listen to them with the expectation that if they were monitoring their comprehension, the inconsistencies would be detected. Unfortunately, children proved to be quite poor at monitoring their comprehension, and the inconsistencies went largely undetected. Although Markman's work ignited a great deal of research in the area of comprehension monitoring that mostly involved the reading of text, questions about the use of the error-detection paradigm arose concerning whether the kinds of reading children used in the research were similar to the kinds of reading in which people normally engage, namely, reading considerate text that is largely error free. Failures to detect inconsistencies may not necessarily indicate a failure to monitor comprehension, but rather, may indicate that the reader is monitoring for purposes unrelated to the implanted errors (Hacker 1994).

Glenberg and Epstein (1985) and Maki and Berry (1984) introduced an alternative paradigm. After reading error-free texts, readers were asked to make metamemory judgments about whether they had comprehended text material well enough to perform accurately on a criterion task, such as judging inferences based on the texts or answering questions about the text. In subsequent research on calibration monitoring or metacomprehension, people were typically asked to read a text, make a judgment of comprehension of the text, and then asked to make a prediction of how well they will perform on a criterion task designed to measure comprehension of the text. Most findings in this literature have corroborated Markman's findings: People are typically poor at monitoring their reading comprehension.

Maki has added significantly to our understanding of metacomprehension. Across 25 studies from her lab, she reported that the mean correlation between ratings of comprehension and test performance was only 27 (Dunlosky and Lipko 2007). Dunlosky, across 36 studies of metacomprehension, also has reported similar low correlations (Dunlosky & Lipko). Maki and associates (2005) identified several factors that could account for such poor monitoring of comprehension. When readers are unfamiliar with the domain being addressed in a text, their judgments of comprehension may be poorly gaged because the judgments are influenced more by their unfamiliarity with the domain than by their comprehension of the text. Difficult text also could contribute to inaccurate judgments. Difficult text usually requires a diligent reader to reread, and judgments of comprehension may be more strongly influenced by the amount of rereading than by actual comprehension. The amount of text that can be recalled after reading could affect the accuracy of judgments. If readers are unable to recall verbatim much of what they have read, the assumption might be made that the text was not understood, even though the overall gist of the text was well remembered. Finally, the kind of text could affect judgments of comprehension. Typically, readers view expository text to be more difficult to understand than narrative text, and the accuracy of judgments of comprehension will vary as a function of perceived difficulty.

There has been much debate and theorizing over the issue of how metacomprehension judgments are made. People's retrospective judgments of comprehension made after reading a text and their prospective judgments of future performance on a test about that text are likely tapping into unique but overlapping psychological processes (Maki et al. 2005). Understanding those processes is something a comprehensive theory of comprehension monitoring or metacomprehension will provide. Such a theory has yet to be proposed. Dunlosky et al. (2002) have suggested that an integration of theories of text comprehension with theories of metacognitive monitoring may lead to productive research that could contribute to such a comprehensive theory.

Important Scientific Research and Open Questions

In spite of the evidence that the accuracy of calibration monitoring or metacomprehension is low, there remains optimism that accurate monitoring and effective control of comprehension (i.e., self-regulated comprehension) holds great promise in educational contexts. This optimism has been fueled, at least in part, by evidence from differing approaches showing that improved accuracy of monitoring does correspond with an increase in learning (e.g., Dunlosky et al. 2005). Moreover, the ability to exercise self-regulation was shown to be an important factor, such that "the efficacy of monitoring to enhance learning was undermined when the task did not afford self-regulation" (Dunlosky et al. 2005, p. 9). This evidence highlights the importance of self-regulation in educational settings and the need to improve students' ability to monitor and control their comprehension.

New lines of research have shown promise in this endeavor. Huff and Nietfield (2009) improved fifth grade students' monitoring accuracy by explicitly teaching comprehension monitoring strategies over a 12-day period. Rawson, Dunlosky, and Thiede (2000, as cited in Dunlosky and Lipko 2007) doubled metacomprehension accuracy simply by having participants reread passages twice, a strategy also known to improve reading comprehension. Thiede, Dunlosky, Griffin, and Wiley (2005, as cited in Dunlosky and Lipko 2007) also nearly doubled accuracy by asking participants to summarize texts after a short delay. They also showed that summarizing texts after reading could be reduced to simply generating five key terms that captured the essence of a text, and still accuracy was improved.

With respect to future research, any setting that involves self-regulated comprehension would benefit from new methods that improve the accuracy of comprehension monitoring. Although individual differences such as verbal ability or test performance have been examined in some detail (Maki et al. 2005), the complex nature of individual differences leaves a great deal of potential factors remaining for exploration. In addition, studies in comprehension monitoring have focused on the learning of text material, but there may likely be other fields of education including verbal communication that would be relevant to and benefit from similar research. Finally, due to the complex nature of comprehension monitoring, researchers should strive to be clear about the types of metacognitive judgments that may be included in any study of it.

Cross-References

- ▶ Calibration
- ▶ Metacognition and Learning
- ▶ Metacognitive Control
- ▶ Reading and Learning
- ▶ Self-managed Learning
- ▶ Self-regulated Learning

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Comprehensive Learning

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Synonyms

Competence development; Everyday learning; Qualification

Definition

All normal learning includes the three dimensions of content, incentive, and interaction (or the cognitive, the emotional, and the social) (Illeris 2002, 2007). However, as the immediate understanding of learning is very often narrowly focused on the acquisition of knowledge and skills and the emotional and social dimensions are more or less neglected, it becomes important to emphasize that even when these dimensions are not considered they are always involved and influence both the learning process and the learning result. Basically, this is due to the way the human brain is working (Damasio 1994; Goldberg 2001) and to the fact that people are social beings – and all this is what the concept of comprehensive learning is referring to.

Theoretical Background

The most fundamental understanding of how human learning takes place is that all learning involves two very different processes. The one process is the *interaction* between the learner and his or her environment. In principle, this process is ongoing all the time when individuals are not asleep. Sometimes it is very vivid, sometimes it is almost fading out. But whenever it contains something which is new or different in relation to what people have already learned, they have a possibility to learn from it.

However, learning only takes place if people also involve themselves in a mental process of *acquisition.* In this process the new information, which learners have perceived from the interaction by their senses, is related to whatever prior learning learners subjectively and often unconsciously find relevant, and through this encounter the learning result is developed. Consequently, this result depends on both the nature of the new input information and the nature of what is already developed in the mind, and this is why different persons learn different things from the same input information.

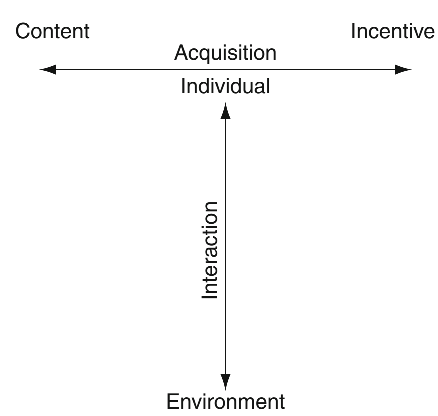
Further, the acquisition process always contains two elements. The one is the learning *content.* This is, as mentioned, usually conceived of as knowledge or skills, but in a comprehensive understanding of learning it may also be opinions, insights, meanings, attitudes, values, conventions, habits, ways of feeling, ways of behaving, working methods – everything which was not there when people were born is something they have acquired by learning. In more general terms, one can also speak about abilities, qualifications, or competences.

But the acquisition process also involves a mobilization of mental energy. It takes place through an active electrochemical process in the brain, and recent brain research has estimated that people averagely spend about 20% of energy on mental processes such as thinking, remembering, and learning. The strength and nature of this mobilization depend on what is usually described as motivation, which has to do with emotion, interest, need, inclination, desire, volition, duty – or with a general term *incentive.* A strong incentive favors a differentiated and durable learning result, which can be activated in a broad range of different situations, whereas a weak incentive will instead lead to a learning result which is superficial, difficult to remember, and only turns up in situations which strongly resemble or relates to the learning situation.

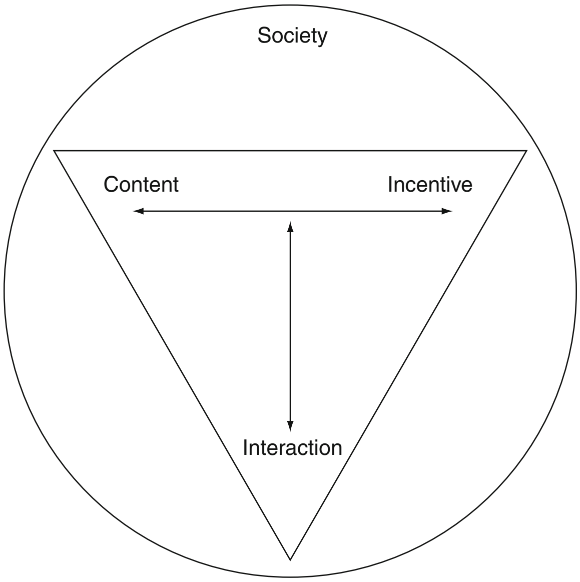
In Fig. 1, the interaction process of learning is depicted as a vertical double arrow between the individual and the environment, and the acquisition process of learning is depicted at the individual level as a horizontal double arrow between the elements of content and incentive.

When the two double arrows of Fig. 1 are framed by a triangle it gives an illustration of the three dimensions, which are involved in all learning. Furthermore, by adding a circle around the triangle, indicating that all learning is situated in and influenced by the environment of a society, Fig. 2 shows the main elements and structure involved in human learning or what may be called a model of comprehensive learning.

The claim of this model is that all learning involves the elements shown and, consequently, that no learning process or learning situation can be fully understood,



Comprehensive Learning. Fig. 1 The fundamental processes of learning (© Illeris 2007, p. 23)



Comprehensive Learning. Fig. 2 The elements of comprehensive learning (© Illeris 2007, p. 26)

analyzed, planned, or in other ways dealt with if all of these elements are not taken into account.

In addition to this, the theory of comprehensive learning as presented by the Danish learning researcher and theorist Knud Illeris (2002, 2007) expounds that the acquisition process can take place in four different ways, the four fundamental types of learning. These are defined in relation to how the learning input is connected and incorporated into already developed learning schemas or *schemata*.

In the case of *cumulative learning*, the learning results from the start of a new schema, that is, there is no existing schema to which it can be related. This happens frequently in the first years of human life, but after a couple of years only in very few situations with the character of rote learning. One example from later life could be the learning of a new pin-code (but even in this case people often try to invent some kind of system, reference, or mnemonic rule, which actually implies that they try to relate the code to some already existing schema). The results of cumulative learning can be characterized as rigid and they can only be recalled in situations which are subjectively narrowly related to the learning situation.

Assimilative learning or assimilation is the everyday type of learning in which a new element is integrated into an already existing scheme. This is, for example, what traditional school teaching is generally aiming at and over the years people learn a tremendous lot of things in this way. Assimilative learning is not very energy demanding, the durability of the learning results depends on how often there was a need to use them, and they can be recalled in all situations when people are mentally oriented toward the schema(s) to which they are subjectively related.

Accommodative learning or accommodation is the other main type of learning which people practice daily, although certainly not as often as assimilation, because it is much more energy demanding. People engage in accommodative learning in situations in which they cannot immediately understand or interpret what is happening, but have a strong incentive to do so. In such cases, learners have the possibility of breaking down parts of one or more existing schemas and reconstruct them in a way so that the new impulse can be included. This is typically experienced as something people come to realize by a sort of break-through, they suddenly understand a structure or a connection, a light is dawned on us, or the like. So it is by accommodative learning that most important new insights are gained or people take a qualitative step in some direction. The learning result has precisely the nature of understanding, it will usually be remembered until it may be changed by new accommodative learning, and it can be recalled in all kinds of relevant situations.

Finally, *transformative learning* or transformation is the most complex and demanding type of learning, in which several schemes are reconstructed involving a change in the organization of the self or the identity. People engage in this type of learning only when they very much need or wish to do so as it is strongly personally demanding and often experienced like the overcoming of some kind of crises. The learning result becomes part of the self, it remains with persons and can only be obliterated by a new transformation or by being completely irrelevant under changed life conditions. Earlier transformative learning was closely related to psychotherapy, but in modern life conditions are for many people changing so often and so radically that this type of learning becomes actualized, and today it is often related to schooling and education in youth and adulthood.

It shall be mentioned that the learning types of assimilation and accommodation were introduced as the two types of equilibrating learning already in the 1920s by *Jean Piaget* (1952). The term of cumulation was as a specific type of learning presented by the Danish psychologist *Thomas Nissen* in 1970 and introduced in English by Knud Illeris (2002). Finally, the term transformative was launched in 1978 by the American adult educator *Jack Mezirow* (1978), but several others have presented similar concepts with different names, for example, Austrian *Sigmund Freud* who already about 1900 spoke about catharsis as the successful result of psychoanalysis (Freud and Breuer 1956), American *Carl Rogers* who in 1951 coined the concept of "significant learning" (Rogers 1951), and Finnish *Yrjö Engeström* who in 1987 suggested the term of "expansive learning" (Engeström 1987).

Finally, it shall be mentioned that the theory of comprehensive learning as introduced by Knud Illeris also includes a theory of *non-learning*. This is, however, taken up in another entry in the encyclopedia.

Important Scientific Research and Open Questions

In a way the understanding of comprehensive learning has been the ultimate aim of all learning theory. For example, behaviorists right back from the late 1800s tried to find the fundamental mechanisms or building stones of learning – but by doing so had to make so many reductions that they limited themselves to the study of a minor field of learning processes. Later especially the German Gestalt Psychologists and the American school of Humanistic Psychology came considerably closer to a comprehensive learning psychology, and in recent times British Peter Jarvis has developed a broad covering theory of learning (Jarvis 2006), partly overlapping with the approach described in this entry. There is certainly no reason to expect that the desire to grasp the complexity of human learning in a coherent and comprehensive way will stop here.

Cross-References

▶ Affective Dimensions of Learning
▶ Approaches to Learning and Studying
▶ Assimilation Theory of Learning
▶ Content-Area Learning
▶ Cumulative Learning
▶ Emotional Learning
▶ Emotions and Learning
▶ Generative Learning
▶ Humanistic Approaches to Learning
▶ Incentives and Student Learning
▶ Learning Defense
▶ Learning Resistance
▶ Motivation, Volition, and Performance
▶ Non-learning
▶ Piaget, Jean
▶ Piagets Learning Theory
▶ Social Learning
▶ Transformative Learning

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Compressed Curriculum

▶ Accelerated Learning

Compulsory Education

▶ Formal Learning

Compulsory Education and Learning

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Synonyms

Democratization of education; Formal education; Mandatory education; Obligatory education; Public education; Required schooling; Universal education

Definition

Compulsory Education refers to the most crucial period of formal education required by law of all children between certain ages in a given country. The period of compulsory attendance is usually determined by the government as the students' age for beginning and ending obligatory formal education. The compulsory education service is generally the duty of the state and is thus provided and/or inspected by the government.

Compulsory Learning: Modern compulsory learning required by formal schooling covers the shaping of the citizen with the skills and knowledge necessary to prepare them to live in an economic and political system.

Theoretical Background

History has seen occasional periods of compulsory education in various places of the world. The more or less regular ones were mostly related to religious teaching and military training. All through history, traditionally accepted informal or non-formal learning of social norms and education for the general public had been a private matter either handled by parents, religious institutions, or communities, which sometimes joined together to pay a teacher to educate their children, primarily in issues of morality (O'Keeffe 2004).

Compulsory public schooling is a relatively new concept that emerged with the appearance of industrial society and especially the nation-state after the French Revolution. During the nineteenth century, a number of states passed laws on compulsory education; in the twentieth century this practice became universal around the world (Green 1990).

The process of nation-state building took place during the Age of Enlightenment, when it was believed that the power of the human mind is ultimately able to regulate everything. According to this view, it is possible to use education to regulate the formation of the state and the domestic market and engage in nation building. Consequently, the three main functions of compulsory public education became the formation of the mind, the making of the citizen, and the training of the educated work force.

Compulsory public schools arose as a part of the establishment requirements of the "nation-state" form of government in the West. Firstly, some factors of production – including labor – needed to be regulated and standardized in order to reinforce the competitive position of each national industry. Accordingly, public education was constructed as a means for the national economy to keep a sufficiently prepared national labor force for production and a relatively uniform domestic consumer market. Secondly, the state was in the process of liberating itself from religion and collecting the social and political power in its hands, and secularization required an institution to replace religious education. Thirdly, education is the means by which a system, a society, and a culture reproduces itself, implants necessary improvements, and resists undue change. The modern state stabilized and strengthened itself on the basis of these three pillars and continued on its route by becoming more and more centralized. The public schools are expected to be qualified according to the laws of the state, can continue functioning as long as they follow its laws and regulations, and have to maintain a constructive relationship with its interests (Green 1990).

It is natural for a state to reflect the philosophy of its founders, and this was so with the nation-states. When a philosophy gains an action plan through a regime, it is inevitable that it will turn into an ideology, thus giving rise to institutions designed to uphold the system. Not all of the nation-states shared the same principles of establishment. There were different shades of ideologies, from autocratic to democratic. It is ironic that the philosophies of economic liberalism (free-market economy) and political liberalism (democracy), which constitute modern society, produced the idea of compulsory education as their tool to institutionalize themselves. The mind of the average individual is formed to think within the principles of a given system, even when the system is defined as free. The rationale of the dominant groups tends to give shape to a particular system. These groups presume to have found the best way to live and think and assume their right to enforce it. Even high-quality compulsory education in most democratic states would be regarded by some critics as mind-control par excellence.

There are two parts to an education system: the connection of its structure and organization to the general system of the country, and its curricula.

National education is connected to the demands of the production system of the country by the state and is given the philosophy of the regime as its guiding principle. The human model the system adheres to should be suited to these basic requirements (O'Keeffe 2004). Equivalent compulsory education is also possible in private schools and parochial schools. The basic structural and organizational criteria all of these types of schools need to meet for the compulsory years are the same: The law determines the rules for establishing schools, organizing the stages of education, determining the number of required years, the school model, the division of labor among the school types, etc., while the program structure and balance, hours per day, and days per year the students are to be engaged in learning are determined by the central authorities. The student assessment standards, the economics of vertical and horizontal movement of students within the education system, diploma and certification equivalency, passages to life, and acceptance in the labor market are all regulated. For these reasons, the system is criticized by some thinkers for supporting an economics of compulsion (Kanpol 1997).

In compulsory education every nation has a unique agenda which makes its curricula national and serves to project the functional content for the formation of the mind, mold the citizen, and train the work force. Again, the soundness of the curricula must be approved; the education and certification of teachers and the quality of teaching must be regulated according to the standards set by the central authorities of the state.

The compulsory curriculum should have certain characteristics: The state sets the official language of teaching, mandates civics courses for various age groups for the entire population of young children, offers courses in mathematics, science, and technology appropriate for different age groups, includes necessary skills for everyday life and the performance of simple tasks, selects those who will be given further education and training for higher technical and academic vocations and professions, and determines the collective culture and values education should promote to enhance the integrity and unity of the nation. The basic compulsory curriculum is expected to act as a harmonizing tool, both for the society and for the market. In addition to the compulsory curriculum, the secular state is also expected to make provisions for the right to religion and freedom of conscience of its citizens, to allow them to learn a religion through alternative means and freely practice it. Accordingly, the public and private schools should not interfere with the religious practices of the parochial schools (see for an overview: Rotberg 2004).

Obviously, the modern state arrogated to itself the power to oversee the education of all of its citizens and the people within its domain according to its interests. The individuals in charge of the state can keep designing the educational system and maintain their dominance as long as the circumstances are favorable.

Primary education is the primary means by which improvements in new generations can be introduced at an early age, thereby benefitting the individual and society. Traditionally, stages of education were, as much as child pedagogy permits, designed in keeping with the technological levels in a country. Accordingly, as the utilization of technology rose, many countries introduced compulsory education through at least the primary stage, often extending to the lower-middle level and some to the level of secondary education. Yet, it is pivotal to understand that the content and length of compulsory education are directly related to the demand for employment in an economy's markets, which is in turn related to the development level of the country. Pushing for longer durations of compulsory education and starting vocational training at later ages creates unfair competition in economies that are not ready for it. Compulsory schooling is not an area where the decision of extending the length of education can be made by looking at others. The length of compulsory schooling must correspond to the demand for employment in the production sector. The system is meant to provide passages to life and offer further stages of education for those whose work is needed at a higher level.

However, the universalization of modern education did not take place as it did in the Western world, even though the promoters were Western. A few of the early nation-states that extended their realm of activity to the colonies carried over the structure and organization of their education systems and schools but never the content of their curricula. Colonial regimes could not provide compulsory education to all of the young natives but rather only educated a select few who would serve the masters with the colonizers' language and their ways of handling work. If missionaries were able to reach those remote places, the rest of the young natives were left to their hands, who were preaching proselytism. Another dilemma of the modern secular nation-state is that it found itself supporting religious indoctrination in the colonies. In the face of the imposing superiority of the colonizer, compulsory national education never came to the foreground in most countries until the second half of the twentieth century (Lauder et al. 2006).

In the course of its development, compulsory education started under the authority of the state as the duty of the citizen and treated the child as a creature of the state. As democratic thought took root in the independent countries, education came to be perceived as the right of the individual and the duty of the state. Compulsory education at the primary level was affirmed as a human right by the 1948 Universal Declaration of Human Rights. Although they are still far from being fully realized, the principles of social justice and equal opportunity in education took priority in the governments' policies. In the interest of a humanization of education, steps were taken to make physical, mental, social, and economic provisions for groups with special needs, and the demand for educational choices brought the individual into focus.

In brief, in the developed countries the compulsory national education and learning policies of the nation-state have served their purposes. Production increased, wealth accumulated, and their citizens enjoyed welfare and democracy. But this was not necessarily the case for many countries.

With the advent of a new era of globalization during the last quarter of the twentieth century, the content and style of education came under debate, because education now had to take into account new needs of continuity and change. The liberal voices in the Western societies demand actual freedom for the family and young individuals and a loosening of compulsory education. On the other hand, the market economy and the government are exerting more pressure to increase the duration of compulsory formal education at both ends of the scale to include the kindergarten years and secondary school and are vying to encompass the whole globe with their ideology.

Important Scientific Research and Open Questions

Four milieus of research are vital for functional solutions for compulsory education and learning (Chappell 2010):

Firstly, decisions on the duration of compulsory education are generally propagated by international organizations, which rely on evidence from the level of technology and the market needs of the developed countries. This is evident in the ILO and UNESCO definitions of the child, UN and WB indexes, OECD statistics, and WTO decisions, which end up making the same recommendations to most countries. The question of the duration of formal and compulsory education has to be studied in its pedagogical, social, and economic aspects and in relation to the individual needs of both developed and developing countries (Lauder et al. 2006).

Secondly, although there is research, the problem of inclusion with regard to geographical, physical, social, economic, and psychological differences will need to be solved at the compulsory primary education level, which is becoming more complicated as mobility, alienation, and bilingualism increase.

Thirdly, there is abundant research on how to bring flexibility to compulsory learning and teacher preparation for this purpose, and much of it is being put to use. Examples include individual learning strategies, the multiple-intelligence approach, constructivist learning, student-based learning, minimal invasive education, freedom from unnecessary guidance, self-organizing group learning, and so on. Future research will need to emphasize the education of the multi-dimensional individual, take into account the free economic and political awareness needs of the child, and decrease the dose of ideology from a powerful center (Kanpol 1997).

Lastly, the libertarians' choice of educating their children on their own has attracted considerable research activity (O'Keeffe 2004). Home schooling and school voucher systems are being applied, both of which have problematic aspects for the parents.

Research on alternative types of basic education and organizational styles may help compensate for the function of compulsory education while at the same time supporting the free upbringing of the multi-dimensional individual.

Cross-References

▶ Aligning the Curriculum to Promote Learning
▶ Curriculum and Learning
▶ Formal Learning
▶ Twenty-First Century Skills

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Computational Emotions

▶ Emotion-Based Machine Learning

Computational Intelligence (CI)

▶ Mathematical Models/Theories of Learning (TL)

Computational Learning Theory

▶ Mathematical Linguistics and Learning Theory

Computational Modeling

▶ Learning Agent and Agent-Based Modeling

Computational Models of Classical Conditioning

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Synonyms

Associative learning; Mathematical models; Neural networks; Pavlovian conditioning

Definition

Computational models of classical conditioning are mathematical models – including neural network models – that describe associative learning in terms of the computation of different intervening variables, such as attention, associations, predictions, and responses. Most times, the models require the use of computer simulations because they are formulated as nonlinear systems for which analytical solutions are unknown or difficult to obtain. The models can reproduce and predict experimental results under different conditions. Explanations for the observed behaviors can be derived from the observation of the model variables in a given simulated experiment.

Theoretical Background

During classical (or Pavlovian) ▶ conditioning, humans and animals change their behavior as a result of their experience with different possible relationships between the *conditioned stimulus* (CS) and the *unconditioned stimulus* (US). Although apparently simple, many models were proposed to account for the numerous experimental results – described at the end of this entry – regarding classical conditioning. Here, we introduce some of the most significant models, briefly explain their mechanisms, and show how they address some important experimental results.

Competition to Gain Associations

Competition Between CSs to Gain Association with a US

Bush and Mosteller (1955) offered a differential equation describing how the CS-US association increased whenever the CS was presented with the US and decreased when the CS was presented by itself. Rescorla and Wagner (1972) modified the Bush–Mosteller (Bush and Mosteller 1955) equation to reflect the assumption that CSs compete to gain association with the US. The ► Rescorla–Wagner Model can describe acquisition, partial reinforcement, generalization, extinction by increasing the US strength, US-preexposure effect, forward blocking, unblocking, supernormal overshadowing, conditioned inhibition, conditioning, overexpectation, and simultaneous feature-positive and feature-negative discriminations. Sutton and Barto (1981) introduced a version of the Rescorla–Wagner model that describes learning as a moment-to-moment ("real time") process. Van Hamme and Wasserman (1994) described a modified version of the Rescorla and Wagner (1972) model. They proposed that the association of a CS with the US decreases when the CS is absent, instead of staying constant as in the original model. In addition to the paradigms listed above, the modified model can explain paradigms recovery from overshadowing and blocking, and backward blocking.

Competition and Configurations

Kehoe (1988) offered a layered network model of associative learning in which the CS inputs, using a competitive rule as the previous models, learn to activate configural hidden units when the US is presented. In turn, the hidden units can become associated with the US. In addition to most of the results explained by the original Rescorla–Wagner model, the model is able to address rapid reacquisition, learning to learn, compound conditioning, and negative and positive patterning. Gluck and Myers (1993) also introduced a model that also incorporates a competitive rule and configural stimuli.

Schmajuk and DiCarlo (SD) (Schmajuk and DiCarlo 1992) presented a "generalized" version of the Rescorla–Wagner (Rescorla and Wagner 1972) rule into a model that also included temporal representations of the CS, the US, the interstimulus interval (ISI) and the intertrial interval (ITI), direct CS-US associations, and indirect CS-US associations through configural stimuli. Configural stimuli are created by combining the internal representations of simple CSs. Configural stimuli are maximally active when some specific CSs are present and others are absent. The model was the first model of classical conditioning to include an individual error term (Blough 1975, p. 20) to limit the associations gained by a single CS. In addition to the results explained by the Rescorla–Wagner model, the SD model also describes – among other paradigms – conditioning with different CS durations, rapid reacquisition, learning to learn, compound conditioning, negative and positive patterning, ISI effects, ITI effects, serial feature-positive (FP) and feature-negative (FN) discriminations, and biconditional discrimination. Schmajuk et al. (1998) extended the SD model to describe how the conditioned response (CR) is determined by both the US and the CS, an important issue in occasion setting.

Competition, Timing, and Configurations

Desmond and Moore (1988) offered a neural network that describes adaptive timing in classical conditioning. Grossberg and Schmajuk (GS) (Grossberg and Schmajuk 1989) presented a model that assumes that a CS generates multiple temporal representations and can describe training with multiple USs. Buhusi and Schmajuk (1999) combined the SD and the GS models to describe timing of the peak CR, training with multiple USs, the temporal specificity of blocking, and temporal specificity in serial FP discriminations.

Competition Without Configurations

Some models incorporate competitive rules but do not use configural representations to solve nonlinear problems. For instance, McLaren and Mackintosh (2000) developed an elemental associative theory which assumes that all stimuli activate a set of common elemental units which provide a solution to negative patterning and biconditional discriminations. The model is also able to describe latent inhibition and perceptual learning. Similarly, Harris (2006) proposed a model in which a limited-capacity attentional mechanism boosts the activation of elements that enter an attention buffer. Therefore, individual elements lose activation when a stimulus is part of a compound. The model explains negative patterning because more elements enter the buffer when A or B are presented separately on A+ or B+ trials, than when they are presented together on AB− trials. On AB− trials, inhibitory associations are formed between the stronger elements of each CS (referred to as A and B) and the weaker elements of the other CS (referred to as b and a), because A and B are in the attention buffer and a and b are outside the buffer. However, this mechanism does not allow the model to describe learning to learn and occasion setting. Among other paradigms, the model also explains positive patterning, biconditional discriminations, latent inhibition, and the results of compound conditioning of an excitor and an inhibitor.

Pure Configurations

Pearce (1987) proposed a purely configural model activated by the whole pattern of stimulation. For instance, presentation of A activates node A and presentation of the compound AB activates a different node AB, which allows the model to readily solve negative patterning and biconditional discriminations.

Competition to Control the Conditioned Response

Miller and Schachtman (1985) proposed the comparator hypothesis, which suggests if the strength of the direct CS-US representation is greater than the indirect representation that results from combining the CS-Comparator CS association with the Comparator CS-US association, the potential for excitatory responding is larger than that for inhibitory responding. Denniston et al. (2001) introduced the extended comparator hypothesis. According to this hypothesis, the CR is still determined by the CS-US association compared with the CS-Comparator CS_1 association combined with the Comparator CS_1-US associations. But, in addition, both CS-Comparator CS_1 and Comparator CS_1-US associations are the result of additional comparisons. More recently, Stout and Miller (2007) offered a computational version of the extended comparator hypothesis. The hypothesis successfully describes – among other paradigms – acquisition, extinction, US-preexposure effect, forward blocking, overshadowing, conditioned inhibition, backward blocking, potentiation, overexpectation, relative validity, conditioned inhibition as a slave process, inhibitory sensory preconditioning, and counteraction between overshadowing and latent inhibition.

Attentional Models

Attention Increases When the CS Is a Good Predictor of the US

Mackintosh (1975) suggested that ► attention to a given CS increases when that CS is the best predictor of the US, and decreases otherwise. The model can be applied to forward blocking, overshadowing, and latent inhibition. At the same time, Grossberg (1975) offered a ► neural network in which CSs compete to activate their input nodes in proportion to their salience and association with the US. Interestingly, the network implements Mackintosh's (1975) attentional rule. Along the similar lines, Moore and Stickney (1982), Schmajuk and Moore (1989), and Schmajuk and DiCarlo (1991) presented real-time versions of Mackintosh's (1975) rule and Grossberg's (1975) networks. Both Moore and Stickney (1982) and Schmajuk and Moore (1989) incorporate simultaneous excitatory and inhibitory associations.

Attention Decreases When a CS Is Predicted

Wagner (1981) offered a Sometimes Opponent Process (SOP) theory. The approach assumes that the type of associations formed between a CS and a US depends on the state of activation of each stimulus. The theory explains the results addressed by the Rescorla–Wagner model and also – among other paradigms – conditioning with different CS durations, ISI and ITI effects, latent inhibition, backward conditioning, conditioned diminution or facilitation of the unconditioned response (UR), and pretrial CS and pretrial US effects. Dickinson and Burke (1996) proposed a revised version of Wagner's (1981) SOP theory that can describe recovery from overshadowing and forward blocking, and backward blocking.

Attention Increases When the CS Is a Poor Predictor of the US

Pearce and Hall (1980) proposed that attention to a given CS decreases when the US is accurately predicted. In addition to most of the results explained by the Rescorla–Wagner model, the model can incorporate simultaneous excitatory and inhibitory associations, explains latent inhibition, the Hall–Pearce effect, and unblocking by decreasing the US.

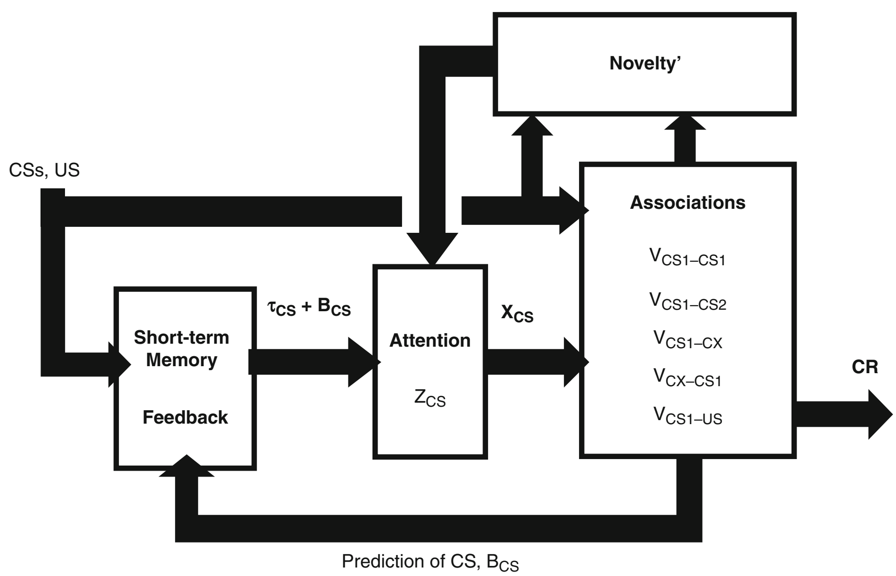
Attention Increases When the CS Is a Poor Predictor of the US or Any Other CS, and When the CS Is Poorly Predicted by Other CSs or the CX

Schmajuk, Lam, and Gray (SLG) (Schmajuk et al. 1996; Schmajuk and Larrauri 2006; Larrauri and Schmajuk 2008; Schmajuk 2009) proposed a neural network model of classical conditioning. Figure 1 shows a block diagram of the network which includes (1) a short-term memory and feedback system, (2) an attention system, (3) an association system, and (4) a novelty system. The SLG includes equations that portray behavior on a moment-to-moment basis, attentional control of the formation and retrieval of CS-US and CS-CS associations, competition among CSs to become associated with the US or other CSs, and reentrant feedback of predictions of the CSs. Attention to the CS is controlled by the CS-US associations, by context-CS (CX-CS) associations, and by CS-CS associations. The feedback system allows the model to describe inferences and cognitive mapping, as well as mediated acquisition, mediated extinction, and mediated attentional changes.

The model describes, among other paradigms, US-preexposure effect, forward blocking, unblocking by increasing the US, unblocking by decreasing the US, overshadowing, conditioned inhibition, supernormal conditioning, overexpectation, recovery from overshadowing, recovery from forward blocking, backward blocking, recovery from backward blocking, conditioning with different CS durations, ISI and ITI effects, latent inhibition, recovery from LI, counteraction and synergy between overshadowing and latent inhibition, external disinhibition, spontaneous recovery, renewal, reinstatement, rapid or slow reacquisition, extinction of conditioned inhibition, conditioned inhibition as a slave process, second-order conditioning, excitatory and inhibitory sensory preconditioning, and learned irrelevance (Schmajuk 2010).

Combined Architectures

Buhusi and Schmajuk (1996) combined the mechanisms of the SLG and the SD models into a model that explains all the results previously addressed by each model. Along a similar line, Le Pelley (2004) presented a model that included excitatory and



Computational Models of Classical Conditioning. Fig. 1 Block diagram of the Schmajuk–Lam–Gray (SLG) (Schmajuk et al. 1996) network. *CS* conditioned stimulus, *US* unconditioned stimulus, τ_{CS} short-term memory trace of the CS, B_{CS} prediction of the CS, z_{CS} attentional memory, X_{CS} internal representation of the CS, $V_{CS1\text{-}CS1}$, $V_{CS1\text{-}CS2}$, . . .,$V_{CS1\text{-}US}$ associations CS1-CS1, CS1-CS2, . . ., CS1-US, *CR* conditioned response inhibitory associations like Schmajuk and Moore (1989) model, an individual error term like Schmajuk and DiCarlo (1992), an "attentional" associability similar to Mackintosh's (1975), and a "salience" associability defined as in the Pearce–Hall (1980) model.

The Evolution of Computational Models of Conditioning

This entry presents a number of models that describe many features of classical conditioning in terms of different computations carried out on the conditioned and unconditioned stimuli. It is clear that the models evolved – and are still evolving – from a few, relatively simple equations to the present complex models able to account for many experimental results. The computational complexity of these models puts our understanding of their workings beyond the ability of our intuitive thinking and makes computer simulations irreplaceable. Interestingly, the complexity of the models frequently results in function redundancy, a natural property of biologically evolved systems that is much desired in technologically designed products.

Some Important Classical Conditioning Results

1. *Acquisition*. After a number of CS-US pairings, the CS elicits a conditioned response (CR) that increases in magnitude and frequency.
2. ► *Partial reinforcement*. The US follows the CS only on some trials.
3. *Generalization*. A CS_2 elicits a CR when it shares some characteristics with a CS_1 that has been paired with the US.
4. *Extinction*. When CS-US pairings are followed by presentations of the CS alone or by unpaired CS and US presentations, the CR decreases.
5. *US-Preexposure effect*. Presentation of the US in a training context prior to CS-US pairings retards production of the CR.
6. *Forward blocking*. Conditioning to CS_1-CS_2 following conditioning to CS_1 results in a weaker conditioning to CS_2 than that attained with CS_2-US pairings.
7. *Unblocking*. Increasing the US increases responding to the blocked CS_2.
8. *Overshadowing*. Conditioning to CS_1-CS_2 results in a weaker conditioning to CS_2 than that attained with CS_2-US pairings.
9. *Conditioned* ► *inhibition*. Stimulus CS_2 acquires inhibitory conditioning with CS_1 reinforced trials interspersed with CS_1-CS_2 nonreinforced trials.
10. *Supernormal conditioning*. Reinforced CS_1-CS_2 presentations, following inhibitory conditioning of CS_1, increase CS_2 excitatory strength compared with the case when it is trained in the absence of CS_1.
11. *Overexpectation*. Reinforced CS_1-CS_2 presentations following independent reinforced CS_1 and CS_2 presentations result in a decrement in their initial associative strength.
12. *Simultaneous feature-positive discrimination*. Reinforced simultaneous CS_1-CS_2 presentations, alternated with nonreinforced presentations of CS_2, result in stronger responding to CS_1-CS_2 than to CS_2 alone. In this case, CS_1 gains a strong excitatory association with the US.
13. *Simultaneous feature-negative discrimination*. Non-reinforced simultaneous CS_1-CS_2 presentations, alternated with reinforced presentations of CS_2, result in weaker responding to CS_1-CS_2 than to CS_2 alone. In this case, CS_1 gains a strong inhibitory association with the US.
14. *Recovery from overshadowing*. Extinction of the CS_1 results in increased responding to the overshadowed CS_2.
15. *Recovery from forward blocking*. Extinction of the blocker CS_1 results in increased responding to the blocked CS_2.
16. *Backward blocking*. Conditioning to CS_1 following conditioning to CS_1-CS_2 results in a weaker conditioning to CS_2 than that attained with CS_2-US pairings.
17. *Conditioning with different CS durations*. Conditioning first increases and then decreases with increasing CS durations when the US is presented at the end of the CS.
18. *Rapid reacquisition*. CS-US presentations following extinction result in faster reacquisition.
19. *Learning to learn*. Learning a CS_1-US association facilitates the subsequent learning of a CS_2-US association.
20. *Compound conditioning*. Reinforced CS_1-CS_2 results in stronger responding to the compound than to the components.

21. *Positive patterning*. Reinforced CS_1-CS_2 presentations intermixed with nonreinforced CS_1 and CS_2 presentations result in stronger responding to CS_1-CS_2 than to the sum of the individual responses to CS_1 and CS_2.
22. *Negative patterning*. Nonreinforced CS_1-CS_2 presentations intermixed with reinforced CS_1 and CS_2 presentations result in weaker responding to CS_1-CS_2 than to the sum of the individual responses to CS_1 and CS_2.
23. *Interstimulus interval (ISI) effects*. Conditioning is maximal at an optimal ISI and gradually decreases with increasing ISIs.
24. *Intertrial interval (ITI) effects*. Conditioning to the CS increases with longer ITIs.
25. *Serial feature-positive discrimination*. Reinforced successive CS_1-CS_2 presentations, alternated with nonreinforced presentations of CS_2, result in stronger responding to CS_1-CS_2 than to CS_2 alone. In this case, CS_1 acts as an occasion setter.
26. *Serial feature-negative discrimination*. Nonreinforced successive CS_1-CS_2 presentations, alternated with reinforced presentations of CS_2, result in weaker responding to CS_1-CS_2 than to CS_2 alone. In this case, CS_1 acts as an occasion setter.
27. *Biconditional discrimination*. Four stimuli are paired in four different combinations, two that are reinforced (AB+ and CD+), and two that are not (AC− and BD−).
28. *CR is determined by both the US and the CS*. The nature of the CR is determined not only by the US but also by the CS.
29. *Timing of the peak CR*. The CR peaks at the time of the US presentation during training (equivalent to responding at the ISI).
30. *Training with multiple USs*. A CS trained with a US presented at different ISIs will present peaks centered at those ISIs.
31. *Temporal specificity of the competition between CSs in blocking*. Blocking is observed when the blocked CS is paired in the same temporal relationship with the US as the blocking CS.
32. *Temporal specificity in serial FP discriminations*. A serial feature-positive discrimination is best when the feature-target interval during testing matches the training interval.
33. *Latent inhibition*. Preexposure to a CS followed by CS-US pairings retard the generation of the CR.
34. *Perceptual learning*. Preexposure to a couple of CSs facilitates the acquisition of a discrimination between them.
35. *Simultaneous excitatory and inhibitory associations*. A CS can simultaneously act as excitor and inhibitor of the CR.
36. *Backward conditioning*. Excitatory conditioning is obtained when the US precedes the CS by a short interval and inhibitory conditioning when the interval is long.
37. *Conditioned diminution or facilitation of the unconditioned response (UR)*. A reduction in the amplitude of the UR that immediately follows a previously reinforced CS.
38. *Pretrial CS*. Presentation of a CS before CS-US pairings decreases conditioning for short CS-CS intervals and increases conditioning for long CS-CS intervals.
39. *Pretrial US*. Presentation of a US before CS-US pairings decreases conditioning.
40. *Recovery from LI*. Presentation of the US in the context of preexposure and conditioning results in renewed responding to the preexposed CS.
41. *Unblocking by decreasing the US*. Decreasing the US in the second phase of forward blocking can increase responding to CS_2.
42. *Hall–Pearce negative transfer effect*. CS-US associations with a weak US slow down subsequent CS-US associations with a strong US.
43. *Counteraction between overshadowing and latent inhibition*. The combined effect of latent inhibition and overshadowing results in stronger responding than that individually obtained with each procedure.
44. *Synergy between overshadowing and latent inhibition*. The combined effect of latent inhibition and overshadowing results in weaker responding than that individually obtained with each procedure.
45. *External desinhibition*. Presenting a novel stimulus immediately before a previously extinguished CS might produce renewed responding.
46. *Spontaneous recovery*. Presentation of the CS after some time after the subject stopped responding might yield renewed responding.

47. *Renewal*. Presentation of the CS in a novel context might yield renewed responding.
48. *Reinstatement*. Presentation of the US in the context of extinction and testing might yield renewed responding.
49. *Rapid or slower reacquisition*. Based on the length of the extinction phase, CS-US presentations following extinction might result in faster or slower reacquisition.
50. *Extinction of conditioned inhibition*. Inhibitory conditioning is extinguished by CS_2-US presentations, but not by presentations of CS_2 alone.
51. *Conditioned inhibition as a slave process*. After CS_1-US and CS_1-CS_2 presentation, extinction of the CS_1-US association results in the elimination of the retardation in conditioning the conditioned inhibitor CS_2.
52. *Second-order conditioning*. When CS_1-US pairings are followed by CS_1-CS_2 pairings, presentation of CS_2 generates a CR.
53. *Sensory preconditioning (Excitatory)*. When CS_1-CS_2 pairings are followed by CS_1-US pairings, presentation of CS_2 generates a CR.
54. *Sensory preconditioning (Inhibitory)*. When CS_1-X/CS_2-X alternated presentations are followed by CS_1-US pairings, CS_2 becomes inhibitory.
55. *Learned irrelevance*. Random exposure to the CS and the US retards conditioning even more than combined latent inhibition and US preexposure.
56. *Recovery from backward blocking*. Extinction of the blocker CS_1 results in increased responding to the blocked CS_2.

Cross-References

► Cognitive Models of Learning
► Computational Models of Human Learning
► Conditioning
► Fear Conditioning
► The Role of Attention in Pavlovian Conditioning

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Computational Models of Human Learning

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Synonyms

Connectionist models of human learning; Neural network models of human learning

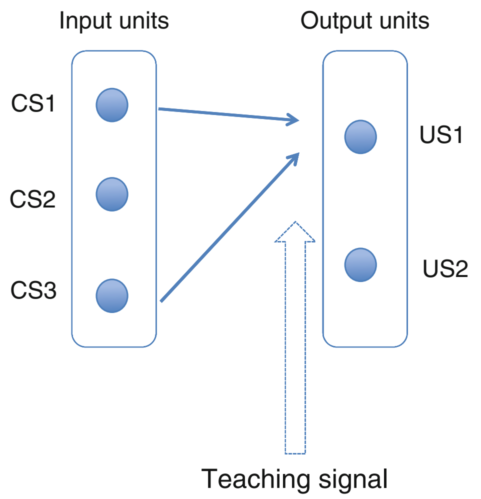
Definition

The aim of computational models of cognition is to propose very specific hypotheses about the underlying cognitive architecture involved in some domain of cognition (e.g., classical conditioning or language processing). For this purpose, an artificial system is simulated, typically as a computer program. To implement such an artificial system, all the computations it performs have to be specified exactly (hence the term computational model). In computational models of human learning, the intention is to study human learning with the artificial system. Hence, a computationally specified learning rule is implemented, and the system learns some task (e.g., past-tense generation of verbs).

Theoretical Background

The aim of computational models of human learning (henceforth abbreviated as models) is to specify how humans learn. This is done by constructing an artificial system (typically implemented on a computer), which is given a (simplified) learning environment and a learning rule that adapts the system to its environment. In the simplest case, the system consists of input units (which code the incoming stimuli), output units (which code the response given by the system), and connection weights between input and output units. For example, in the study of classical conditioning, the system may have input units that code for particular conditional stimuli (CS) and output units that code for particular unconditional stimuli (US) (see Fig. 1). The model's task is to predict the US given each configuration of CS. Learning consists of changing the connection weights between the units of the system. The learning rule specifies how exactly connections should be changed given the current CS and US.

Two indices can be distinguished to determine how plausible a particular model is as a theory of the domain of interest. One index of plausibility of a model is how well its performance compares to learning by humans (*behavioral plausibility*). One aspect of behavioral plausibility is whether the model is up to tasks of the same complexity as humans. This refers to the computational power of a model. Another aspect of behavioral plausibility is whether its performance measures (e.g., error rates, error patterns, or reaction times) are similar to those of humans. Besides behavioral plausibility, a second index is how well the model adheres to biological principles (*biological plausibility*).



Computational Models of Human Learning. Fig. 1 Learning procedure in supervised model

These two indices are often in a trade-off relation (see below).

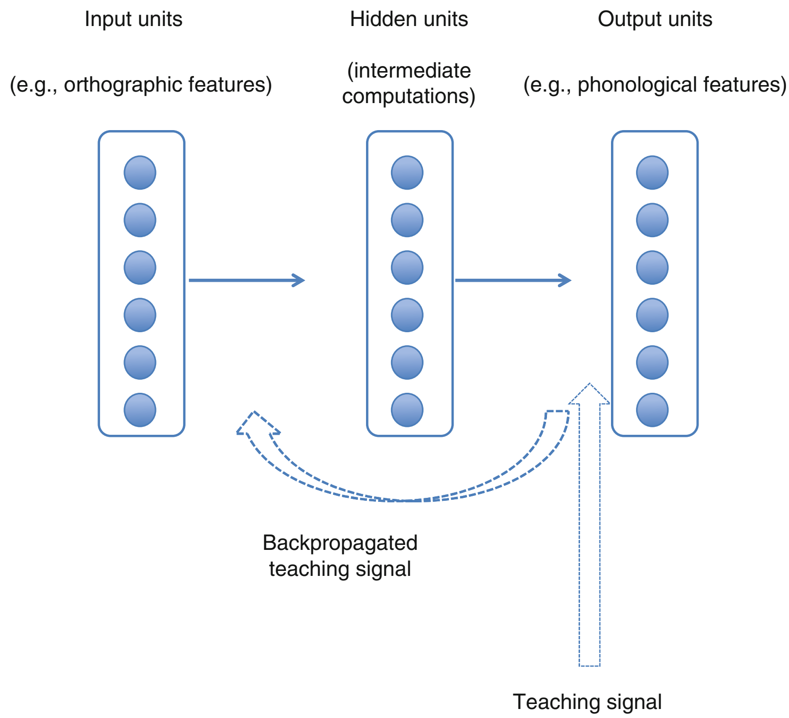
Historically, two types of model have been influential: supervised and unsupervised models. In supervised models, an external teaching signal is injected in the computational system and used in the model's learning rule (Fig. 1). This is then used to adapt the configuration of the system. A seminal model from this class is the Rescorla-Wagner model to account for aspects of classical conditioning. One of the main attractions of this model was that it was able to account for the phenomenon of blocking, observed in human and nonhuman organisms, which holds that CS–US relations are learned only when the US is not predictable. This attests to the behavioral plausibility of the Rescorla-Wagner model, and made it extremely popular as a model of relatively simple learning tasks. On the other hand, there is little direct biological evidence for the existence of this type of learning rule in the human brain, except in very specific areas such as the cerebellum (Gluck and Myers 2001).

Researchers in cognitive science have applied and extended this model to human learning in domains well beyond conditioning. For example, Rumelhart and McClelland (1986) applied it to learning to generate the past tense of English verbs. Attesting to its behavioral plausibility, it was observed that during learning the model exhibited similarities to the error patterns of children.

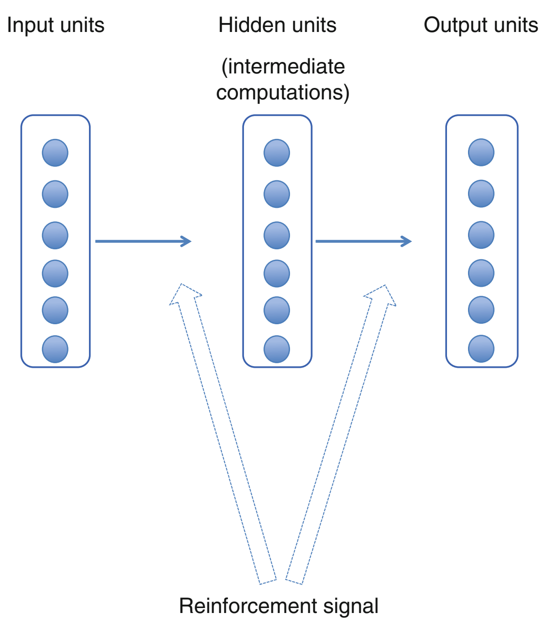
To make this simple model more powerful, researchers have extended it to include hidden units (see Fig. 2). In this way, the computational power of the model greatly increased. As a simple example, determining the parity (odd/even) of the number of input units that is active is impossible without hidden units, but it becomes possible when hidden units are added. This type of model is applied to domains where complex input–output transformations are required such as reading aloud (orthography-phonology mapping), sensory coordinate transformations (e.g., from eye- to head-centered object representations), and mental arithmetic. To train a model containing hidden units, a learning rule is specified in which the training signal given at the output level is passed backward in the network (from output to hidden units, a process called back propagation; see Fig. 2). Unfortunately, this process is even less biologically plausible than the Rescorla-Wagner learning rule.

Unsupervised models do not receive teacher signals, as the name suggests, and are therefore more biologically plausible. These models trace back to the influential proposal by Donald Hebb that if two units (cells) are active together, their connection weight will be increased. Learning rules based on this principle are called Hebbian learning rules. Much data attest to the biological plausibility of this learning rule. However, models based (only) on Hebbian learning typically have much less computational power than supervised learning models and are in this sense less behaviorally plausible.

A third class of models is reinforcement learning models. They strike a middle ground between the two traditional classes of model (supervised and unsupervised models) and may be called weakly supervised. They have recently become very popular because of their biological plausibility. In such models, there is no feedback to the system about what activation level each of the units should have (as is the case in supervised models), but instead a broad reinforcement signal is provided which informs the system whether its performance was "good" or "bad" (Fig. 3). One reason for the recent interest in reinforcement learning models is the remarkable convergence on similar concepts in two traditionally separated research streams, computer science and neurophysiology. In computer science, so-called temporal difference models of reinforcement learning learn from a signal expressing the difference



Computational Models of Human Learning. Fig. 2 Learning procedure in supervised model with hidden units (back propagation)



Computational Models of Human Learning. Fig. 3 Learning procedure in reinforcement model

between two successive evaluations of the validity (good/bad) of the environment (Sutton and Barto 1998). In neurophysiology, neurons in the monkey brain stem have been identified that exhibit the same properties as these temporal difference signals. In particular, when learning that a cue predicts reinforcement, these neurons initially fire when the rewarding stimulus is presented, but after training they respond to the cue and no longer to the reinforcement itself. These brain stem neurons are dopaminergic and project widely to the subcortical basal ganglia and prefrontal cortex. Recent research shows that reinforcement learning models are also behaviorally plausible (Frank et al. 2004).

Important Scientific Research and Open Questions

In recent years, the dual aims of behavioral and biological plausibility are more and more successfully integrated. Some domains of human learning still remain challenging, however. In particular, high-level reasoning is at this time not easily accommodated by the type of models described here. To address this, recent models endow biologically plausible models with extra computational power. One interesting development is to add hierarchical representations to reinforcement learning models (Botvinick et al. 2009) which can be used for hierarchical planning. Another is to add randomly connected neurons that have different activation states at different time points, which can be used for precisely timed action sequences (e.g., dancing; Buonomano and Maas 2009).

As mentioned above, Hebbian learning in itself is not very powerful; however, it can be used as a building block for more powerful rules. For example, a reinforcement learning rule can be constructed by modulation of a Hebbian learning rule. Hebbian learning in a particular cortical region could be increased whenever a dopaminergic reinforcement signal arrives there. This even allows construction of learning rules with the same computational power as backpropagation learning (Roelfsema and van Ooyen 2005). In recent years, other neurotransmitters have been proposed to provide important learning signals for the cortex (e.g., serotonin, noradrenalin). Also these neurotransmitters could operate by modulating Hebbian learning processes. Recent research investigates how these neurotransmitters interact with cortical areas to obtain powerful devices for learning in the human brain (Doya 2008).

Cross-References

► Computational Models of Classical Conditioning
► Connectionist Theories of Learning
► Reinforcement Learning

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Computational Models of Learning

► Cognitive Models of Learning

Computational Natural Language Learning

► Machine Learning of Natural Language

Computer Adaptive Testing

► Adaptive Evaluation Systems

Computer Simulation Model

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Synonyms

Simulation model; Simulator model; System simulation model

Definition

A computer simulation model is a computer program or algorithm which simulates changes of a modeled system in response to input signals.

Theoretical Background

Simulation has become a widely used tool for training and for research on human interaction with complex work and learning environments. A simulation is defined as a working representation of reality (Jones 1980). Further, a simulation may be an abstracted, simplified, or accelerated model of a process or system which allows exploration where reality is too expensive, complex, dangerous, fast, or slow (de Freitas 2006).

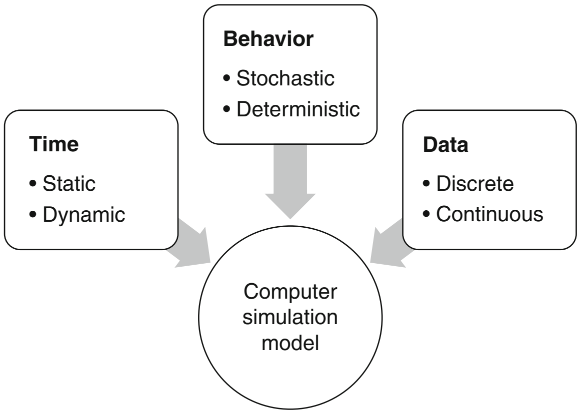
The richness in the use of simulations to support learning is clearly documented in the literature and numerous research projects. Training programs using simulations have been successfully applied in the fields of flight training, health care education, dental education, command and control training of large incidents, team-based decision making, simulations for the training of firefighters, teacher education, and many other domains (see Ifenthaler 2009).

Technically, computer simulations which model some specific domain of reality allow users to change input variables by manipulating objects or entering data. The results of the simulation are represented as dynamically generated graphs, numeric displays, and texts (de Jong and van Joolingen 2008). Hence, three major components of simulations can be identified: (1) the simulation model, (2) the execution of the simulation model, and (3) the analysis of the executed simulation model. First, the simulation model may be based on declarative, conceptual, or functional understanding of a specific phenomenon to be simulated. Second, the execution of the simulation model is defined through specific algorithms, e.g., serial execution, parallel execution, or fuzzy execution algorithms. Finally, the analysis approach of the executed simulation model may focus on the input–output processes, the verification of results, the visualization of output data, and the validation of the simulated output. However, a sufficient simulation requires a well-founded model of the simulated phenomenon – the computer simulation model.

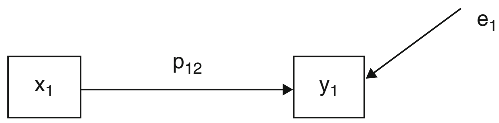
Initially, a simulation model has been realized as a mathematical model. These mathematical models have become a useful tool in physics, chemistry, biology, economics, engineering, and social sciences. However, the ad hoc manipulation of variables from outside a predefined mathematical model is not possible. Accordingly, the application of computer programs or algorithms enables higher variability and stronger individualized simulation runs. This is primarily realized through the change of parameters of the computer simulation model.

Computer simulation models include three major determinants: Time, behavior, and data (see Fig. 1). The factor *time* defines a static or dynamic computer simulation model. A static computer simulation model includes variables and parameters which are not time dependent. Dynamic computer simulation models include variables and parameters which model time-varying states of the simulated phenomenon. The factor *behavior* defines a stochastic or deterministic computer simulation model. Stochastic computer simulation models are characterized through their indeterminacy in future evolutions which are described by probability distributions. Deterministic computer simulation models include no randomization in the development of future events of the simulation. A special deterministic model is a chaotic computer simulation model whose behavior cannot be entirely predicted. The factor *data* defines a discrete or continuous computer simulation model. Discrete computer simulation models include variables which change only at specific points in time at which an event occurs. Continuous computer simulation models include variables which change in a continuous way including infinite number of states.

The development of adequate computer simulation models requires the definition of the three major determinants; time, behavior, and data. Besides these factors, numerous design decisions must be taken into account, e.g., the application area, the programming framework, the user interface, the system support, the simulation engine, and so forth (for details see Fishwick 1998; Sulistio et al. 2004).



Computer Simulation Model. Fig. 1 Determinants of computer simulation models



Computer Simulation Model. Fig. 2 Simple path model including one independent variable

Important Scientific Research and Open Questions

From a cognitive science perspective, learning initiated by simulation involves explorative thinking and inductive and analogical reasoning. This places high cognitive and metacognitive demands on the learner, who must generate hypotheses and test them by accomplishing learning tasks as well as performing experiments in the simulated environment. Accordingly, simulations of complex processes and systems often require complex problem solving. Complex problem solving requires iterative steps of hypothesis testing as well as increased time for constructing appropriate mental models. Mental models are constructed in order to hypothesize and understand the structure of the simulation process or system and to simulate transformations of these processes and systems mentally.

Currently, research focuses on the development of adequate computer simulation models for the social and cognitive sciences. Ifenthaler (2009) suggests the application of path models for the development of computer simulation models. Path models include path coefficients, which are standardized regression coefficients showing the direct effect of an independent variable on a dependent variable. Additionally, regression residuals are considered in the equations. A simple path model including one descriptive variable x_1 is shown in (1):

$$y_1 = p_{12} * x_1 + e_1 \tag{1}$$

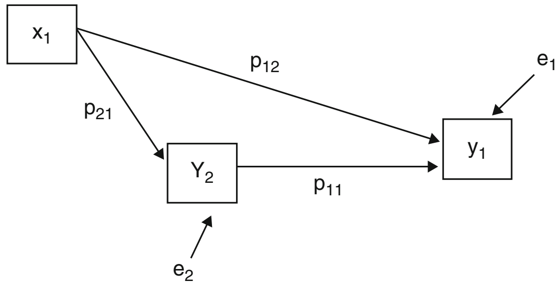
e_1 indicates the residual of the path model.

The path model described in (1) can be visualized as follows (see Fig. 2):

If the path model in Fig. 2 is expanded with an additional descriptive variable, it can be specified by the following path equations (see (2), (3)):

$$y_1 = p_{11} * y_2 + p_{12} * x_1 + e_1 \tag{2}$$

$$y_1 = p_{21} * x_1 + e_2 \tag{3}$$



Computer Simulation Model. Fig. 3 Expanded path model

The visualization of these two equations results in the following path model (see Fig. 3):

The path coefficients can be used to decompose the correlations in the path model into direct and indirect effects (the total causal effect of variable *i* on variable *j* is the sum of the values of all the paths from *i* to *j*). The total causal effect on y_1 is the sum of all direct and indirect effects (see (4)):

$$eff_{total} = p_{12} * p_{11} + p_{21} \tag{4}$$

Applying the mathematical assumptions of a path model and the related path coefficients, we are able to transform a path model into equations for realizing the necessary computer simulation model. All equations of direct and indirect effects from the path model are included in the computer simulation model.

Future research should address a formal and structural comparison of available computer simulation models as well as a meta-analysis of simulation models and their effects in the field of learning and instruction.

Cross-References

► Modeling and Simulation
► Simulation and Learning: The Role of Mental Models
► Simulation-Based Learning

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Computer-Assisted Instruction (CAI)

▶ Interactive Learning

Computer-Assisted Learning (CAL)

▶ Interactive Learning

Computer-Assisted Training (CBT)

▶ Interactive Learning

Computer-Based Collaborative Learning

▶ Online Collaborative Learning

Computer-Based Education (CBE)

▶ Interactive Learning

Computer-Based Learning

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Synonyms

Computer-based training; eLearning; Multimedia learning; Online learning

Definition

In computer-based learning (CBL), the computer is used for instructional purposes whereas the computer hard- and software as well as the peripherals and input devices are key components of the educational environment. CBL assists individuals in learning using multiple representations of information for a specific educational purpose. Common innovative realizations of CBL to improve teaching and learning are hypertext, simulations, and microworlds.

Theoretical Background

The development of the first integrated circuit by Noyce and Kilby in the late 1950s marked the dawn of the role of computer technology in education. In the following years the microcomputer was developed featuring audio, colors, peripherals, and input devices, as well as a graphical user interface (Ifenthaler 2010). In CBL, the computer is regarded as the key component of the educational environment. Individuals are assisted in learning from multiple representations of information for a specific educational purpose. CBL provides promising opportunities for fostering meaningful learning (Lajoie 2000). Common innovative realizations of CBL to improve teaching and learning are hypertext (text that links to other information), simulations (characteristics of a system can be influenced through change of underlying variables), and microworlds (environment where individuals explore information and construct or change the environment).

In the 1960s and 1970s, PLATO (Programmed Logic for Automated Teaching Operations) was the first computer system which was used for programmed instruction (Lockee et al. 2008). Programmed instruction has influenced modern instructional design processes and laid the foundations for computer-mediated instruction (e.g., Glaser 1965; Hartley 1974; Stolurow 1961).

Especially the 1980s and 1990s produced a huge range of CBL, e.g., computer-assisted learning (McDougall 1985), multimedia learning environments (Mayer 2001), hypermedia environments (Dillon and Jobst 2005), or simulations, games, and microworlds (Reiber 2005). However, since the early days of CBL it has been subject of scrutiny and debate with arguments being advanced both in support of and against the use of computers for learning and instruction.

A quarter of a century ago Greenfield (1984) took up the topic of new media and communication technologies and discussed their possible effects on the learning and behavior of children. The topic was approached from a fundamentally positive, albeit critical perspective. New technologies were understood as cultural artifacts that demand complex cognitive skills for their use which are not learned or taught in school, but rather only through active manipulation and practice in everyday life. However, the discussion in the 1980s was dominated more by critical voices. Günther (1986), for instance, warned vehemently against an overly hasty introduction of computers in schools and was only prepared to accept it if the schools also offered regular outdoor excursions and field trips. The well-known proponent of educational reform von Hentig (1987) recommended waiting as long as possible to offer computer courses to school students.

Haft (1988) commented on this discussion by pointing out that every technological advancement in history has led to a perceived loss of immediacy, belief, and confidence in one's own experiences but that in most cases the pessimistic predictions concerning the proliferation of new technologies has turned out to be ungrounded. Whereas ardent educational reformers warned of the dangers of the computer, parents and children were quick to see the potential of the computer, and the PC made its way rapidly into children's bedrooms – more rapidly, at any rate, than into schools.

Schools began reacting to this challenge in the 1990s and made systematic efforts to improve the information technology competence of their students. *Computer literacy*, the ability to work competently and effectively with computer technologies and programs, advanced increasingly to the fore of pedagogical interests (Seel and Casey 2003), and a *basic education in information technology* became a real hit in these years (Altermann-Köster et al. 1990). Educators tried just about everything they could to teach their students how to use computers. More important than these changes in the classroom, however, was the fact that information and communication technology were increasingly becoming a part of the daily lives of children, teenagers, and adults.

Like it or not, the general proliferation of computer-based information and communication technologies is irreversible, and computers now play an important role in human learning in everyday life as well as at educational institutions (Ifenthaler 2010).

Important Scientific Research and Open Questions

Today, there is widespread agreement among educational theorists on the point that educational applications of modern information and communication technologies can be made more effective when they are embedded in *multimedia learning environments* created to enable productive learning. CBL environments should be designed to enable learners to explore them with various amounts of guidance and construct knowledge and develop problem-solving methods independently (Ifenthaler 2009; Seel et al. 2009). The key to success is seen not so much in how the information is presented as in how well the learners can manipulate the different *tools* available in the CBL environment on their own. However, empirical research also shows that students often struggle while confronted with a CBL environment (Lajoie and Azevedo 2006). Extensive use of a computer as a *tool* for solving problems can help learners to concentrate on understanding and solving problems rather than the finished product or the acquisition of declarative knowledge and can awaken their curiosity and creativity. Several characteristics of the new technologies contribute to this effect:

- The new information and communication technologies are interactive systems.
- The learners themselves are placed in control of what and how they learn.
- The computer can model real situations and complex systems and simulate their behavior.

- The learners can receive immediate feedback on their activities.
- In many cases the computer can also execute complex operations (e.g., simulations of dangerous situations) which cannot be executed as well or at all by other media (Seel and Dijkstra 2004).

Indeed, when one considers that modern computers can represent all forms of information and knowledge needed for learning and problem solving, the current state of computer technology seems to make the tedious process of integrating traditional media (such as texts, graphics, video) technically superfluous and obsolete. Moreover, recent developments in the area of interactive software provide unique possibilities for creating virtual learning environments and modeling complex systems without professional guidance. The options for independent development of interactive environments are manifold, and the graphical capabilities of new software programs include exciting animations and simulations of highly complex processes. Last but not least, everything is comparatively inexpensive and thus readily available to the broader public (Ifenthaler 2010).

However, the advantages of CBL lie not only in the area of education, but also in administrative, financial, and social domains. The main educational advantages may be summed up as follows:

- The *independence of learning and teaching from the constraints of time and space*: Learners (e.g., college students) can follow a course from any point on the earth and at any point in time, and the courses can be offered worldwide.
- The *individuality of learning*: Courses can be adapted to the needs of each individual learner and course materials can be reused and rearranged as often as one likes (provided that they are organized in modules).

Although these advantages are actually all beyond question, the discussion on the educational use of learning in the digital age often suffers from being limited to the technological potential of information and communication technologies (Seel and Ifenthaler 2009). The technological possibilities for designing CBL environments are doubtlessly great, but the pedagogically significant question as to how learning can be supported effectively is sometimes left out of the picture.

Much of what we discussed above is already dated in a technological as well as a pedagogical sense and will in a few years be hardly more than a historical footnote like the Jasper Woodbury Series (Cognition and Technology Group at Vanderbilt 1997) or the goal-based scenarios (Schank et al. 1994). We believe that the days of pre-programmed online courses are numbered, in which the learner – as in the classical paradigm of programmed instruction – is viewed more as an audience than as an active constructor. In the near future, learners will be the constructors of their own environments and create the structures of the content units on their own.

Cross-References

► Blended Learning
► Learning Management Systems
► Model-Based Learning with System Dynamics
► Programmed Instruction

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Computer-Based Learning Environment

► Model-Based Learning with System Dynamics

Computer-Based Learning Environments

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Synonyms

Computers as cognitive tools; Computer-enhanced learning; Technology-rich learning environments

Definition

The term *computer-based learning environments* (CBLEs) refers to a broad array of uses of technology that are aligned with theories that support learning. Researchers who design and evaluate CBLEs come from multiple disciplines including, but not limited to, education, psychology, and computer science. Given this interdisciplinarity, there is a proliferation of phrases describing the uses of technology in education, for instance, intelligent tutoring systems, computer-assisted instruction, interactive multimedia learning environments, computers as cognitive tools, simulations, microworlds, computer-supported collaborative learning, E-learning, pedagogical agent-based environments, and virtual reality environments. The phrase CBLEs encompasses this broad range of technology where the learning environment is designed for an instructional purpose and uses technology to support the learner in achieving the goals of instruction (Lajoie and Azevedo 2006).

CBLEs have been designed in a variety of disciplines, for a variety of learner populations, ranging from elementary school learning to university education and beyond to non-formal learning situations in the real world and in professional practice. CBLEs are typically discipline specific (e.g., mathematics, physics, medical training), and the format of instruction varies (e.g., drill-and-practice, problem-based, immersive, case-based) based on the theories that underlie their design.

Theoretical Background

Technology is ubiquitous but its mere presence does not necessarily lead to better learning. CBLEs are environments that align the design of the environment with theories and empirical research about what leads to effective learning experiences. CBLEs can be designed to help students during thinking, problem solving, and learning by providing them with opportunities to use their knowledge in complex contexts and meaningful activities or situations.

There is a long history of CBLEs and consequent theories underlying their design. Behaviorist stimulus-response theorists such as Skinner (1957) influenced the use of computer-assisted instruction where multiple-choice questions could be administered to students automatically. The computer was seen as a "teaching machine" whose key benefit was its ability to provide immediate feedback to reinforce correct responses or to correct incorrect responses with predetermined solutions. Questions would increase in difficulty as learners demonstrated mastery at a particular level. Once students mastered one set of problems they would then move on to the next level of difficulty.

The influence of developments in the information sciences (e.g., mathematical theory of communication, computer programming, systems analysis) contributed to the development of cognitive theories that viewed learning as a form of information processing. Instead of just looking at learning outcomes, problems could be decomposed into the individual cognitive processes needed to solve them. The development of domain-specific cognitive models made it possible to identify and remediate errors that learners might make in the context of a particular problem-solving situation. CBLEs could be designed to use complex production rules to detect and correct student misconceptions (Anderson 1996) and provide appropriate feedback based on the identification of learning impasses. Theories of expertise led to the identification of complex models of competency that could be used to help the less proficient become more proficient more efficiently. CBLEs could use such models as exemplars for novices to observe, as well as benchmarks for dynamic forms of assessment of individual learners, to determine the type of feedback learners would need in the context of learning.

Situated learning theories describe how human thought and action are best supported in contexts that provide opportunities for learners to integrate their information from multiple sources (Greeno 1989). Learning theories are now looking at the intersection between cognition, motivation, and the social context in which learning takes place. Cultural and societal issues are also considered in learning theories that consider communities of learners and communities of practice as a factor in learning. CBLEs can provide situated learning experiences, where learners interact with complex problem-solving situations, using multiple media (e.g., text, video, animations, and diagrams). Theories of intelligence and aptitude tell us that learners differ in how they learn, for example some learners respond better to verbal material and others respond better to visual material. There is not one best way to teach individuals given these individual differences and consequently CBLEs that use multiple representations can help to meet a variety of individual learning needs (Moreno and Mayer 2007). Furthermore, CBLEs can scaffold learners in the context of their learning by providing adaptive technological assistance in the form of computer tutoring (e.g., intelligent tutoring systems) or pedagogical agents or with human assistance of those more proficient. The social context of learning and collaboration using CBLEs is a field in itself where complex methodologies document how human dialogue by peers and mentors leads to better understanding.

Important Scientific Research and Open Questions

As technology becomes part of our everyday lives, educators need to incorporate such changes in their classrooms. Researchers can support educators by demonstrating the effectiveness of CBLEs and by designing more interactive and engaging environments. Technology can respond to individuals through its actions be they text-based, verbal, or reactions of personal/pedagogical agents or avatars. The prevailing view is that the more natural the interaction with computer-based learning environments, the less awkward and more realistic the learning situation. Identifying the optimal level of realism to promote effective engagement and learning is an open question, though many researchers strive toward passing Turing's (1950) test of machine intelligence, whereby a reasonable person would not be able to distinguish between a human and computer response to his or her actions. Given that situating learning in authentic, meaningful, and engaging settings is the goal of current CBLEs, it is very likely that we need to keep moving forward in pursuit of artificial intelligence techniques applied to education practice. One particular area of current research is in the use of natural language techniques and dialogue. For example, Graesser has developed AutoTutor (www.autotutor.org), a system that engages in dialogue with students learning about Newtonian physics and adaptively responds using a combination of explanations, prompts, and feedback on errors.

A second approach to enhancing engagement is to detect and respond to changes in students' emotions and levels of motivation as they use a CBLE. This builds on the research of Lepper, Malone, and others that shows that successful human tutors are able to maintain and direct continuous attention to both cognitive/informational and motivational/affective factors, and formulate specific goals to maintain students' confidence, challenge, curiosity, and control. Sensor technology can be used to detect emotion through a combination of physiological measures (e.g., EEGs, seat position, eye gaze, facial expression, skin conductance). A relatively new area of research is investigating how these physiological data can be used concurrently with observational data, self-report, and outcome data to create motivating learning circumstances using CBLEs. Building on previous work in gesture and face recognition, Lester has devised computational models of affect recognition (automatically recognizing students' affective states) and affect expression (that automatically recognize and classify students' affective states). Lester, Moreno, Azevedo, and VanLehn are each currently examining how pedagogical agents (intelligent virtual tutors) can employ language, facial expressions, and gestures to engage learners and create effective learning experiences.

Engagement is a necessary, but insufficient, condition for learning. New and innovative assessments need to be created concurrently with new CBLEs to ensure that we are collecting evidence of learning in these new contexts. This can be a challenge given that different domain-specific competencies are assessed in each CBLE. One innovative approach to this challenge is the use of stealth assessment, a process by which learner performance data is continuously gathered during the course of playing/learning. Stored in dynamic, learner models, inferences are continuously drawn about student competencies (Shute et al. 2009). Furthermore, many of the more inquiry-based CBLEs provide a significant amount of learner control to students in project-based activities where students may create their own content. This type of CBLE is a challenge to traditional modes of schooling and is often best assessed in the context of design experiments and other participatory methodologies.

Cross-References

▶ Agent-Based Modeling
▶ Computer-Based Learning
▶ Computer-Supported Collaborative Learning
▶ Human-Computer-Interaction and Learning
▶ Interactive Learning Environments
▶ Technology-Enhanced Learning Environments
▶ Virtual Reality Learning Environments

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Computer-Based Music Instruction (CBMI)

▶ Technology in Music Instruction and Learning

Computer-Based Training

▶ Computer-Based Learning

Computer-Enhanced Learning

▶ Computer-Based Learning Environments

Computerized Learning Environment

▶ Interactive Learning Environments

Computer-Mediated Communication

▶ Discourse in Asynchronous Learning Networks
▶ Online Collaborative Learning

Computers as Cognitive Tools

▶ Computer-Based Learning Environments

Computer-Supported Collaborative Learning

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Synonyms

Computer-supported cooperative learning

Definition

Computer-Supported Collaborative Learning (CSCL) refers to the activity of peers interacting with each other for the purpose of learning and with the support of information and communication technologies (ICT). CSCL also refers to the learning that results from such activity, and to the research field that studies such activity. We examine the components of "learning," "collaborative," "computer," and "supported" in turn, before commenting briefly on the scope of the research field.

Learning generally involves changes in behavior of some agent as a result of experience, but CSCL includes various conceptions of learning that differ on (for example) what is taken to be the agent of learning. These differences are consequential for CSCL, so are summarized in the theoretical discussion of the next section.

Collaborative activity is most strictly defined as tightly coordinated activity in which participants seek to maintain a joint conception of a problem and its solution. Collaboration is sometimes contrasted with cooperation, in which learners divide up work to be done in parallel, occasionally coordinating their activity (Stahl et al. 2006). However, in practice, CSCL researchers and practitioners study both collaboration and cooperation, and even competitive structures that motivate students' efforts.

The term *computer* in CSCL is now understood broadly to include all ICTs, such as the Web, mobile phones, and ubiquitous and embedded computing, as well as desktop and laptop computers. Some of CSCL's results and insights can apply to other technologies, including those predating the information revolution, to the extent that they are designed and applied in ways that support and guide interaction among peers leading to learning.

CSCL may take place in face-to-face settings in which students interact directly with each other. In such settings the ICT may *support* collaborative learning by serving as a resource or guide that improves the learning interaction, for example, with representational tools for organizing students' ideas, agents that make suggestions, or scripts that structure student interaction. The ICT may also itself be the object of study. CSCL may also take place in online settings where ICT plays the additional role of the medium through which participants interact. In the online case, CSCL may be synchronous (interacting at the same time), or asynchronous (interacting by leaving messages or other artifacts accessed by others at different times).

The research field of Computer-Supported Collaborative Learning is supported by its own conference series by the same name, by the International Journal of

Computer-Supported Collaborative Learning, and the Springer (formerly Kluwer) Computer-Supported Collaborative Learning book series, among other venues. The research field has been characterized by one if its founders, Timothy Koschmann, as "a field centrally concerned with meaning and practices of meaning-making in the context of joint activity and the ways in which these practices are mediated through designed artifacts" (Stahl et al. 2006). Understood in this way, CSCL is not merely a specialization of collaborative learning within educational psychology, but rather is relevant to any field of inquiry concerned with intersubjective meaning-making (Suthers 2006).

Theoretical Background

Work undertaken in CSCL is based on several alternative theoretical views of how social settings bear upon learning (Suthers 2006). Some theories treat the individual as the locus of learning. Research under a *knowledge-communication* epistemology examines how to more effectively present knowledge in some medium, or how to otherwise communicate in ways that cause or support learners' acquisition of the desired knowledge. CSCL has moved decidedly away from views of learning as transfer of knowledge, and toward more constructivist and interactional views. *Constructivist* epistemologies emphasize the agency of the learner in constructing knowledge based on her efforts to make sense of her experiences. These may include social experiences in which new ideas are encountered, some of which may conflict with one's own ideas, and the expectation to defend one's own ideas. Some *interactionalist* epistemologies emphasize learners' efforts to find "common ground" and share information with others. Other interactional epistemologies, such as *group cognition*, treat learning as a process in which new ideas are jointly created through interaction. Here the agent of learning is the group rather than the individual, and learning itself is not just a product of interaction but actually consists of interaction. *Participatory* epistemologies bring the agency of learning to the community level: becoming a member of a community of practice is not merely a matter of an individual internalizing the knowledge and practices of that community, but also a process of the community's own self-replication and growth as it takes on new members.

Four major empirical strands can be discerned as influential in CSCL. The *experimental* paradigm, which typically compares an intervention to a control condition by carefully manipulating variables, has roots in cognitive and educational psychology. Experimentalism has been critiqued for failing to examine learning in specific cases of interaction (most analyses aggregate the behavior of multiple individuals), and for weak ecological validity due to the contrived situations needed to control variables. The *iterative design* tradition continuously improves artifacts intended to mediate learning and collaboration, with changes at each iteration driven by theory, observation, and engagement of stakeholders. This tradition derives from CSCL's roots in computer science and human–computer interaction. Traditions of *interaction analysis* in CSCL are influenced by conversation analysis and ethnomethodology, and examine how learning is accomplished in practice. These traditions privilege participants' own behavior and accounts rather than prior theoretical accounts, and typically focus on short episodes of interaction (Stahl et al. 2006). Such methods are well suited to existentially quantified claims, yet are less developed for making predictive generalizations. Finally, *sociocultural analysis* examines how institutional, cultural, and historical processes, structures, and tools bear upon learning, identifying how infrastructures produced at meso- and macro-scales influence learning in specific settings (Jones et al. 2006).

Important Scientific Research and Open Questions

Some relevant findings in CSCL derive from or overlap with the field of cooperative learning in education, which has studied the conditions that affect whether groups are beneficial for learning (e.g., group composition, reward structures, task characteristics, role specialization, various forms process guidance). Due to space limitations, this article provides a sampling of important trends within the field of CSCL itself and associated open questions. See Stahl et al. (2006) for a brief history of CSCL and pertinent references. A sampling of earlier research in CSCL may be found in Koschmann et al. (2001).

A common strategy in CSCL is to identify interactions that lead to learning and then try to get students to engage in these kinds of interactions. Based on socio-cognitive conflict theory and research showing the beneficial effects of attempting to articulate and justify one's own ideas, a major thrust of work in CSCL has sought to engage learners in *argumentation* with each other (Andriessen et al. 2003). Here, "argumentation" is not used as synonymous with verbal conflict, but rather to include cooperative interactions in which participants take a critical stance to ideas and their justifications, exposing them to tests and comparing alternative points of view in an effort to reach greater understanding. Interventions explored include ICT-supported role-playing, sentence-opener prompts that make different argumentative moves explicit, and representational notations and tools that support argumentation by making ideas and their interrelations and evidence visible. The effectiveness of different computer-mediated communication tools for supporting argumentation has also been studied. Argumentation scripts lead us to the next major area of research in CSCL.

Learners do not spontaneously engage in practices that lead to effective collaborative learning, such as coordinating their joint efforts, referencing each others' contributions, and building and evaluating grounded arguments. Furthermore, they may be distracted from such practices when attention must be allocated to managing the ICT and their group processes. For these reasons, *collaboration scripts* are studied as ways to make learners' interactions more productive for learning (see Fischer et al. 2007, on which this paragraph is based). Scripts are understood in psychology to refer to memory structures that guide people in understanding and participating in social action sequences, in computer science as formal structures that may be visualized or used to drive computational processes, and in education as practical means for organizing learning activities. Scripts may apply at a "macro" level in advance of a session by organizing who is collaborating on what task in what roles; and at a "micro" level, by specifying the processes by which learners conduct their activities. Research examines issues such as the most effective ways to structure interaction (e.g., scripting collaboration versus scripting reasoning), the conditions under which collaboration scripts are internalized so that external support can be removed, the use of scripts to bridge knowledge differences in heterogeneous groups, and how scripts can drive software agents participating in the collaboration. Critical issues include the coerciveness of scripting and the danger of denying participants' agency in learning to direct their own learning.

Technology-centric work in CSCL is in a delicate position, requiring an understanding of the concept of *affordances*. Affordances are relationships between agents and their environments, relationships that offer potentials for action. Because human beings are cultural agents, our use of technologies is not determined by their properties. Affordances are enacted through the meaning-making activities of learners. Yet, affordances are not purely socially constructed or entirely relativistic: the properties of technologies make some kinds of practices more available than others. Consequently, designers of technologies for CSCL cannot treat their designs as directly controlling or determining learning. Rather, an indirect approach is called for in which designers offer potentials for desirable practices and examine how these potentials are actually taken up (Jones et al. 2006). Open questions lie in the design and study of fundamentally social technologies that are informed by the affordances and limitations of those technologies for mediating intersubjective meaning-making (Suthers 2006).

An advantage of studying learning in small groups is that participants will display their understanding to other participants in ways that are also accessible to educators and researchers (Stahl et al. 2006). Small groups are also of interest because they lie at the boundary of and mediate between individuals and a community: the knowledge building that takes place within small groups becomes "internalized by their members as individual learning and externalized in their communities as certifiable knowledge" (Stahl et al. 2006). Yet there has been insufficient research that actually makes connections between these levels of analysis: most work examines either individual learning outcomes or group processes, and does not trace connections between these levels. Also, the ways in which institutions select and implement the infrastructures of CSCL that influence local interaction need to be made visible (Jones et al. 2006). Hence, some CSCL researchers are examining ways to bridge between levels of analysis.

The development of the Internet and Web into technological infrastructures for networked individualism and sociability has led to new challenges. CSCL research has traditionally focused on strong relationships of cooperation and collaboration, but is now faced with the question of whether to also embrace proliferating "weak ties" of the new networked society, or instead to offer a critical voice in favor of strong relationships (Jones et al. 2006). At the community level, CSCL has also focused on cohesive groups who share an enterprise and repertoire, raising the question of whether "communities of practice" or "networked learning" based on weak ties is more productive with respect to the learning of the individual participant (Jones et al. 2006). Promising topics for research in the networked society include identifying how the mutability and mobility of digital artifacts can serve to recruit participants in new social arrangements that make new forms of learning possible, the conditions for productive entanglement of multiple individual trajectories of participation, and how the social affordances of technologies operate over larger spans of time and larger collections of actors (Suthers 2006).

Cross-References

- ► Asynchronous Learning Networks
- ► Collaboration Scripts
- ► Collaborative Knowledge Building
- ► Collaborative Learning
- ► Collaborative Learning and Critical Thinking
- ► Collaborative Learning Strategies
- ► Collaborative Learning Supported by Digital Media
- ► Collective Learning
- ► Communication and Learning
- ► Online Collaborative Learning

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Computer-Supported Collaborative Work

► Collaborative Learning Supported by Digital Media

Computer-Supported Cooperative Learning

► Computer-Supported Collaborative Learning

Computer-Supported Cooperative Work

► Collaborative Learning Supported by Digital Media
► Online Collaborative Learning

Computer-Supported Intentional Learning Environment

► Online Collaborative Learning

Computer-Supported Learning

► Situated Prompts in Authentic Learning Environments

Computer-Task Paradigm

Experimental procedure in which animals use joysticks, touchscreens, or other manipulanda to respond to computer-generated stimuli in accordance with game-like tasks, typically with rewards dispensed automatically for correct responding.

Conation

► Motivation and Learning: Modern Theories

Concentration

► AIME (Amount of Invested Mental Effort)
► Alertness and Learning of Individuals with PIMD

Concept Formation

► Concept Learning
► Constructive Induction
► Learning by Chunking

Concept Formation: Characteristics and Functions

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Synonyms

Concept learning; Semantic classification

Definition

Concept formation has been a central issue of philosophy since ancient times (Ros 1989/1990), and it is generally assumed that cognitive activities such as learning and remembering, reasoning, problem solving, language comprehension, and decision making presuppose the existence of a system of concepts in memory. Concepts are defined as cognitive abstractions which represent classes of things, events, or ideas. In general, concepts are seen as natural semantic categories which help to unite things, qualities, and occurrences on the basis of a similarity of characteristics. In fact, one of the most striking characteristics of human thinking is the ability to make generalizations on the basis of specific experiences and to form concepts which represent concrete ideas (e.g., what a CHAIR is) as well as abstract constructions of our thought (e.g., what TRUTH is). More specifically, the construct "concept" is defined in psychology on the basis of three attributes: psychological meaning, structure, and transferability (e.g., Eckes 1991).

Theoretical Background

The Meaning of Concepts

From an early stage in the development of semiotic functions, humans learn to use concepts in order to cope effectively with the complexity of the world. People classify objects in their environment as CLOTHES, FURNITURE, INSECT, TREE, BIRD, etc., and they use words of natural languages to express concepts and to communicate them with others. This leads to the question of the relationship between word and concept.

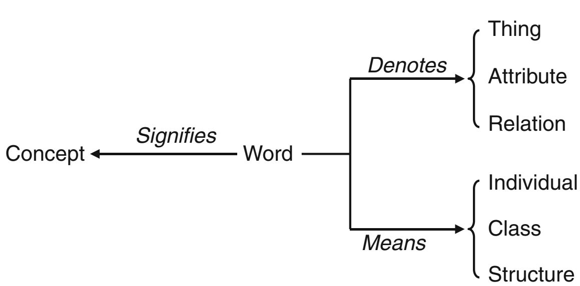
To make an initial distinction, a *word is a unit of language* that can be characterized grammatically whereas a *concept is the result of cognitive abstraction.* Linguistic expressions fulfill both a significative role, namely as words, and a communicative role as a part of speech acts. As signifiers, *words make sense and have a meaning*: The meaning of a word is that which it refers to as a linguistic sign whereas its sense is that which it *expresses.* The sense of words in natural languages is always an "intended sense" which is expressed intentionally by the speaker.

The *distinction between the sense and meaning* of words goes back to the essay "On sense and meaning" by Frege (1892/1980), in which a distinction is made between the functions of signification and meaning in language. According to this view, the bearer signified by a proper name is understood to be the meaning of the name while the mode of "existence" of the bearer constitutes the sense of the name. For instance, the same planet exists both as "morning star" and as "evening star," and the same person exists both as "Josef Ratzinger" and as "Pope Benedict XVI." Two linguistic expressions may thus have the same meaning but a different sense. A general outline of this conception is provided in Fig. 1.

Words allow people to communicate with their surroundings and to have a *conception* of things and occurrences in the world. However, this presupposes that words are considered as objects of knowledge. If people use words as a means of communicating their knowledge they must be able to retrieve both the signs and meanings of the words they wish to use. The German philosopher Lorenz (1987) therefore emphasized the contrast between *factual knowledge*, which is independent of concrete speech acts, and *linguistic knowledge*, which is knowledge about objects as well as about possibilities of expressing those objects in language and communicating them.

▶ *A single word I say*
It's only words,
And words are all
I have to take your heart away.
The Bee Gees: Words, 1968.

From a psychological point of view, Bruner et al. (1956) determined that the meaning of a concept is the result of the association of perceived and learned characteristics of an object with attributes stored in memory. In other words, the *psychological meaning of a concept* is determined by an individual's existing knowledge of the world. It is formed by associating information about things, qualities, and events with attributes defined in memory. These attributes do not only contain information on the qualities and characteristics of



Concept Formation: Characteristics and Functions. Fig. 1 The relationship between concept and word in terms of three-dimensional semantics

objects and events designated and denoted by words; they also contain a personal component which includes emotional judgments based on subjective experiences and feelings. It is known that even strong emotions can be associated with concepts. This *connotative meaning* of concepts changes in the course of an individual's development in dependence on learning experiences and communication with others. Parallel to the continuous development of cognitive operations and semiotic functions, humans learn concepts which are more and more abstract (e.g., SOCIAL WELFARE, TOLERANCE).

Attributes of Concepts

Concept formation begins with a determination of the common characteristics or attributes of things, qualities, and events which can then be united to form a semantic category on the basis of these similar attributes. However, the attributes used to form these categories can vary in quantity and quality (relevance, distinguishability). A quadrilateral, for example, has four relevant attributes: a closed shape, a plane figure, four angles, and four sides. The same four attributes plus two additional ones – right angles and equal sides – are used to define a square. Thus, the attributes "right angles" and "equal sides" are relevant for the concept of SQUARE but not for that of QUADRILATERAL.

Cognitive psychology differentiates between primary and secondary attributes of concepts, depending on whether they ascribe to objects concrete characteristics (e.g., form, location, color, and size), functional characteristics, or characteristics based on opinions (e.g., characterizing an object as "beautiful," "good to sit on," etc.). Accordingly, a distinction can be made between *sensory* and *categorical concepts*. Clearly, sensory concepts classify objects on the basis of concrete attributes and are represented in memory primarily by means of these attributes, whereas categorical concepts are formed on the basis of non-concrete and functional characteristics. The formation of categorical concepts extends to *abstract concepts*, which result from cognitive processing and must not correspond to any concrete object or occurrence. Nevertheless, even exceedingly abstract concepts like ETERNITY or ENDLESSNESS still may have a residual concreteness for many people. Abstract concepts encompass not only many attributes of the underlying class of concepts; they are also often related to other concepts in the same subject domain. This led Klix (1984) to the conclusion that the more abstract a concept is the more relations it will have to other concepts.

The formation of concrete concepts and many categorical concepts is grounded in the assumption that attributes are separable, that is, easy to distinguish from one another. However, in many cases this condition is not fulfilled, causing the semantic contour of a concept to become indistinct and "blurred." Actually, many of the concepts humans operate on in daily life are vague, and in consequence the boundaries between these concepts are not only indistinct but also variable. However, the less possible it is to differentiate between attributes the more difficult concept formation becomes.

Another important structural feature of concept formation has to do with the *relations within a concept*. The first step in the process of associating the attributes of a concept is to establish the common and distinguishing attributes of the objects of a domain. Objects with common attributes can then be combined to form a class. Thus, all *attribute concepts* are based on the one-attribute relation which ascribes certain characteristics to the objects. Examples are SUGAR – sweet, JAGUAR – spotted, FROG – croak, DOG – bark, etc. The *attribute relation* is also used to construct semantic categories by testing whether things, qualities, and events can be combined to form a class on the basis of common characteristics. This, however, presupposes that the attributes are separable. Then it is possible to distinguish between several "relations within a concept," for example (a) the *contrastive characterization* of two concepts with reference to a certain attribute (e.g., HIGH – LOW, GIANT – DWARF, MOUNTAIN – VALLEY) and the *comparative characterization* of two concepts (e.g., SICK – INFIRM, WIND – STORM, JOG – RUN).

A far-reaching assumption of semantics and psychology states that concepts are hierarchically organized. Two complementary aspects of concept hierarchies are emphasized in the literature: the *inheritance* of attributes and the *intensification* of attributes. The inheritance principle, which states that a subordinate concept always includes the attributes of its superordinate concept (as a more comprehensive class), can be understood as a cognitive operation of specialization. The complementary operation consists in generalizing abstractions, which result in an *intensification of attributes*. This is because superordinate concepts are formed on the basis of the conjunctive association of the common attributes of the concepts subordinate to them. More specifically, a subordinate concept is characterized by all attributes of its superordinate concept plus the attributes which characterize it and distinguish it from the other concepts on the same level of the concept hierarchy. Take for instance the concepts BIRD and MAMMAL: Birds have warm blood like mammals, but they do not have mammary glands (or udders) and their offspring are not born live. But despite these differences, both birds and mammals possess common attributes and are thus both classified as belonging to the TETRAPODA (vertebrates with four legs or limbs), a class which also includes reptiles and amphibians.

The hierarchical organization of attribute concepts correlates to a great extent with the degree of concreteness of the attributes. This also has consequences for the assignment of things, qualities, and events to concepts on various hierarchical levels. Hoffmann (1986) and others have shown that the first concept to be identified as such is the one which is characterized by both the smallest and most comprehensive set of concrete attributes. This concept, which represents the "lowest common multiple" of the concrete attributes of objects, is referred to as a *primary concept* (e.g., Hoffmann 1986) and is the point of departure for *addressing* the significant attribute classes in memory.

From an extensional standpoint, a concept may be defined by a class containing an undefined amount of objects. Many semantic classes, however, comprise only a single object – the MOON, the EARTH, the PRESIDENT OF THE UNITED STATES, FRANCE. Other concepts comprise many objects (e.g., SONGBIRD = [nightingale, lark, robin, titmouse]), and others even comprise an infinite amount of objects (e.g., RATIONAL NUMBER). Many concepts cam be characterized by examples and counterexamples. Any rectangle is a good example of QUADRILATERAL, but a bad example of TRIANGLE; and it is also a bad example of ANIMAL and all other concepts which do not signify geometric forms. Finally, the examples of a concept also vary in how open they are to sensory perception. On the one hand, there are examples that one can see, hear, smell, or feel, but on the other hand, there are concepts whose examples are not perceptible and thus also difficult to represent (e.g., ATOM, GENETIC CODE).

Generally, a concept is defined by the attributes which all members of the semantic category it signifies have in common. But Wittgenstein (1953) demonstrated with the example of the concept GAME that not all members of a category share all of the same attributes. Some games, like chess or checkers, require a board, others require cards, balls, or paddles, and some (like hide-and-go-seek or guessing games) do not require any equipment at all. Many games are competitions, some are not. Some people who play games do it for fun, whereas others treat them like a sport and complain about stress and pressure. This example makes it easy to understand why Wittgenstein chose to work with the term *family resemblance* and to assume that objects are combined to form a class because they *resemble* each other and not because they possess all or even most of the same attributes. Whereas Wittgenstein argued along logical principles, some decades later Rosch was able to demonstrate in numerous individual experiments that many natural categories include members which are judged to be more typical for a category than the rest. In one experiment, for instance, Rosch (1975) presented to subjects the names of members of everyday categories (e.g., vegetables, furniture) and asked them to rate the items in a list according to their value for the category. The results revealed that carrots, for instance, are judged to be more typical for the category VEGETABLES than pumpkins but less typical than peas. Typical items share many attributes with the other members of the same category, but only few with members of other categories. Correspondingly, atypical representatives of a category have only little in common with other items in the same category, whereas they may have more or less attributes in common with items from other categories. *Typicality* is strongly dependent on the degree of family resemblance. In psychology, the most typical member of a semantic category is referred to as the *prototype* (see Eckes 1991). It is assumed that the prototype is at the center of a category, whereas atypical members are at its margins. The prototype serves as a point of reference for the classification of objects in a category.

Transferability of Concepts

Once individuals have learned a concept, there are several ways in which they can use it in other situations: (1) New things, qualities, or events can be assigned to a concept; (2) concepts can be ordered in a hierarchy through the identification of superordinate or subordinate relations; (3) a concept can be used as an aid in understanding and solving a problem; (4) concepts facilitate the learning of other concepts. The first two usages have to do with the classification or, as Novak (1998) says, the *assimilation of concepts*, the last two with the *transfer* of concepts.

A central aspect of the transferability of concepts is that humans are capable of learning how to learn concepts. In fact, they acquire new concepts throughout their lives and learn with time the principles of acquiring new concepts. Referring to Piaget's seminal work on the development of the concepts of numbers, room, and time, Aebli (1987) described concept formation as a structural process which can be stimulated effectively by external influence (e.g., instructional methods).

Important Scientific Research and Open Questions

As said in the introductory part of this entry, concept formation has been a central issue of theoretical and practical consideration since ancient times. Ros (1989/1990) described in full detail the history of the philosophical consideration of "rationale and concept" from Socrates to Wittgenstein. In his description of the modern concept of "concept," Ros centers on the definition of concepts as directly accessible subjects of self-consciousness that are created autonomously by the human mind. This corresponds to Locke's understanding of concepts (or general ideas) as templates of existing mental images and Leibniz's idea of concepts as capabilities to imagine "forms" as well as to Kant's definition of concepts as capabilities to produce many optional mental representations of concrete objects in compliance with a rule. This understanding of concepts, which has since been modified and revised by Wittgenstein, is clearly the fundamental basis of modern philosophy of language and psychology. Actually, apart from behaviorism all new movements of twentieth century psychology referred more or less explicitly to Kant and his followers in discussing the formation of concepts. This can be demonstrated by the example of the Würzburg school of psychology (e.g., Ach 1921) and its focus on the so-called imageless thoughts (i.e., conscious sets, awarenesses, and thoughts). Additionally, developmental psychology has focused on concept formation since Piaget's seminal work on the formation of the concepts of number, space, time, etc., in children (Wetzel 1980). Actually, Piaget's epistemology and early research on cognitive development initiated an abundance of empirical studies on childhood concept learning and the origin and evolution of everyday concepts (see, e.g., Novak 1998).

In addition, Piaget also had a strong influence on the ascent of cognitive psychology in the 1950s. For instance, concept formation as semantic classification was at the core of Bruner's work (e.g., Bruner et al. 1956) whereas Ausubel and others focused on the hierarchical organization of concepts (see the entries on "► Assimilation Theory of Learning" and "► Meaningful Verbal Learning"). Since the paradigm shift known as the "cognitive revolution," concept formation has become an important research topic throughout the world, and especially again in Europe. This can be illustrated by the research of Aebli (1980), a Swiss psychologist and student of Piaget, and East German psychologists such as Hoffmann (1986) and Klix (1984). Altogether, it can be said that concept formation is probably the most important branch of cognitive psychology ever. In consequence, it has also become an important topic for cognitive science and informatics with its emphasis on machine learning and artificial intelligence (cf. Brodie et al. 1984; Sowa 1984).

Machine learning refers to cognitive psychology, often especially to Bruner et al. (1956), and focuses on the development of *computational approaches to concept formation* and learning. Machine learning may apply different approaches depending on how concept formation is to be modeled. Discriminative approaches do not entail an explicit model of a concept but only a procedure for discriminating between members and nonmembers of mutually exclusive contrasting categories, whereas distributional approaches operate with a model of a concept as a probability distribution and classify new instances as members of a category if their estimated probability of family resemblance exceeds a threshold. Distributional approaches are regularly based on Bayesian learning and include "novelty detection" techniques which operate not only with positive examples but also with negative examples of principled generalization. The correspondences between approaches of cognitive psychology and machine learning are obvious, and it can be said that computational approaches attempt to close the gap between human and machine concept learning (Chater et al. 2006).

Cognitive psychology and its research on concept learning not only had a strong influence on machine learning and artificial intelligence but in particular also on educational approaches to concept learning. As a consequence, there have been instructional principles pertaining to concepts in the literature of educational psychology for decades (see, e.g., Aebli 1987; Klausmeier and Ripple 1971). However, probably the most successful instructional application of research on concept formation was the idea of visualizing relations within and between concepts by means of maps and graphs (Novak 1998). There are hundreds of studies that demonstrate the effectiveness of concept mapping as a tool for structuring and assessing domain-specific knowledge as well as for learning new concepts.

Cross-References

- ► Abstract Concept Learning in Animals
- ► Bruner, Jerome S.
- ► Categorical Learning/Category Learning
- ► Categorical Representation
- ► Concept Maps
- ► Concept Similarity in Multidisciplinary Learning
- ► Conceptual Change
- ► Conceptual Clustering
- ► Language Acquisition and Development
- ► Meaningful Verbal Learning
- ► Prototype Learning Systems
- ► Psycholinguistics and Learning
- ► Word Learning

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Concept Learning

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Synonyms

Categorization; Classification; Concept formation

Definition

A ► concept is a mental representation of a class of objects or events that share one or more common properties. Some concepts are fairly concrete, in that the objects or events they encompass share certain easily detectable physical features (e.g., the concept *red* refers to a certain range of light wavelengths, the concept *horse* refers to a largely domesticated mammal species with distinctive and well-recognized head and body shapes). Other concepts are more abstract and difficult to pin down in terms of specific, observable characteristics (e.g., the concept *cousin* is defined by a particular familial relationship; the concept *freedom* is defined by the lack of physical and social constraints on one's behavior). On average, concrete concepts are learned more quickly and easily than abstract ones.

Theoretical Background

Some early behaviorists attempted to explain concept learning in terms of the *strengthening of certain of S–R associations;* for example, children will form the concept *red* if they are consistently reinforced for saying "red" in response to red objects. Although this explanation might at least partly explain concept learning in very young children and nonhuman species, it did not hold up to close scrutiny in laboratory research with older children and adult humans, who appear to mediate their overt responses to particular classes of objects with internal, mental responses (e.g., Kendler et al. 1962).

Cognitive psychologists have offered several alternative explanations regarding the nature of concepts and concept learning, at least for human learners. Perhaps the first prominent theory grounded in a cognitively oriented framework was one involving *hypothesis testing* (Bruner et al. 1956). In particular, when confronted with a label that is believed to represent an unknown class of objects, a learner forms and tests a series of hypotheses regarding features that might possibly define the concept (e.g., color, shape) either singly or in combination. However, laboratory studies supporting this perspective were highly contrived and unrepresentative of real-world concept-learning situations.

Several other cognitively oriented theories do appear to have some relevance to real-world concept-learning situations. For example, Eleanor Rosch (e.g., Rosch 1978) has proposed that many concepts are formed, at least in part, by acquiring mental *prototypes* that capture the features of a typical, average member of a concept (e.g., a sparrow-like creature might be a good prototype of the concept *bird*; a penguin or ostrich would be less representative of birds in general). Other theorists (e.g., Ross and Spalding 1994) have suggested that mental representations of many concepts may be based on a variety of examples, or *exemplars*, that reflect the variability that concept members may show (e.g., the concept *fruit* might be mentally represented by such diverse exemplars as apples, bananas, and grapes) and can include atypical concept members (e.g., although most *mammals* give birth to live young, platypuses and a few other mammal species lay eggs).

When concepts are not easily represented by prototypes or exemplars, a mental *feature list* of category members may be involved (e.g., Ward et al. 1990). In particular, learning a concept may involve learning the one or more features that characterize many or all instances of the concept, along with probability estimates for each feature. Identifying an object or event as an example of a particular concept, then, is a matter of determining whether the object or event includes enough of these features to qualify.

The various theoretical explanations just described are not necessarily mutually exclusive (Ormrod 2008). Quite possibly, mental representations of concepts include (1) prototypes that capture a typical, average concept member; (2) exemplars that reflect variability among concept members; (3) a set of features that facilitate identification of new examples; and (4) one or more automatic responses to concept members. Hypothesis testing may come into play in situations where a learner is given a concept label and a set of examples and non-examples but no explicit definition.

Important Scientific Research and Open Questions

Researchers have observed the ability – and, some might say, a natural tendency – to categorize objects and events in human infants as young as three months old, and also in several other mammal species. Acquisition of any particular concept may occur over a period of time, with learners sometimes initially showing under-generalization (i.e., they fail to recognize all concept members) or over-generalization (i.e., they mistakenly include nonmembers as being examples of the concept) before fully mastering the concept. Also, learners may sometimes mistakenly identify the essential features of concept members; for example, many young children restrict their understanding of the concept *animal* to creatures with four legs and a lot of fur, thus disqualifying fish, insects, and people as animals.

Several factors have been found to facilitate concept learning in instructional settings. Explicit definitions that identify critical features of concept members are helpful, as are visual or other modality-specific representations that highlight those features. Illustrative examples are beneficial as well, but it is also important to show non-examples that are "near misses" to category membership (e.g., a spider is not an *insect* because it has eight legs instead of six).

Much of the existing research on concept learning has involved studies with adults (or in some cases nonhuman animals) learning artificial concepts in laboratory settings. Such research is helpful in illuminating cognitive processes that might underlie concept learning. However, the extent to which the principles derived from such research can be generalized to more natural concept-learning phenomena has yet to be determined.

Cross-References

► Abstract Concept Learning in Animals
► Categorical Learning
► Categorical Representation
► Concept Formation: Characteristics and Functions
► Meaningful Verbal Learning
► Prototype Learning Systems
► Schema(s)

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Concept Learning in Pigeons

► Categorical Learning in Pigeons

Concept Map

► Concept Similarity in Multidisciplinary Learning

Concept Mapping

It is a method to construct graphic representations of information. There are several technical tools supporting the process of producing concept maps. Such maps include concepts (usually represented as circles or boxes) and relationships between concepts represented as lines which are specified by words. Unlike mind maps concept maps are hierarchically structured. Concept mapping has been shown to help different groups of persons in education, research, and management.

Concept Maps

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Synonyms

Conceptual maps; Knowledge maps

Definition

Concepts can be defined as objects, events, situations, or properties that possess common critical attributes and are represented by icons or symbols, such as key words (Ausubel 2000). Concept maps are external network structures that allow two-dimensional, spatial processing along preconstructed or to-be-constructed connecting lines. In its simplest form, a concept map would consist out of two concepts and a linking word for example “cats – are → mammals.” Although originally conceptualized as hierarchical structures (Novak and Gowin 1984), current conceptualizations use a broader scope that is the basis for the following definition: Concept maps provide an external network-like representation of knowledge structures. They consist of spatially grouped nodes with key words representing concepts, connecting lines representing the semantic connection of concepts, and labels on the lines specifying the kind of semantic relation. Careful utilization of colors and shapes further enhance the possibilities to represent conceptual similarities, differences, and connections. The inferential power of maps can be exemplified by a map that subsumes cats as mammals and that also includes the mammal property that the children of most mammals have milk teeth. Thus, learners can infer that it is very likely that kittens also have milk teeth.

There are various more or less closely related subtypes and relatives of concept maps. Concept maps in which the set of connections such as P (part) or C (characteristic) is fixed are sometimes labeled knowledge maps. Even more formalized and used mainly in computer science is the Unified Modeling Language (UML). Tree structures that are arranged around one central concept and in which the concepts are written directly onto the links are termed mind maps.

Theoretical Background

Concepts and relations can be conceptualized as key-constructs of knowledge and thought. Epistemological foundations of concept maps can be found within the realm of graphical knowledge representation that are based on logic and the study of ontology. While logic provides the formal structure and rules of inference, ontology deals with questions about entities relevant for the respective domain and how such entities can be grouped, related within a hierarchy, and subdivided according to similarities and differences (Sowa 2000; see also ► Ontology and Semantic Web in this encyclopedia). The earliest known semantic network appeared in a commentary on Aristotle’s categories, by the philosopher Porphyry in the third century A.D. (see Sowa 2000).

From an educational point of view, concept mapping is based on the assimilation theory of David Ausubel (see Novak and Gowin 1984; Ausubel 2000). In short, assimilation theory points out that all new information is linked to relevant, preexisting aspects of the learner’s cognitive structure and that both, the newly acquired and the preexisting structure are modified in the process. The assimilation of new information includes establishing relations between same-level concepts (combinatorial learning), generalization processes creating new subsumers (superordinate learning), and anchoring a new idea below a higher-level anchoring idea (subsumption learning). According to Ausubels hierarchical view of knowledge, these processes of concept assimilation are perceived as the major learning activities of school children and adults (Ausubel 2000). Related to these processes described by Ausubel, hypotheses about knowledge representation distinguished between inter-concept relations and intra-concept relations (e.g., Klix 1980). Inter-concept relations are relations between concepts and events that have been directly observed and experienced for example "the boat is in the water." Intra-concept relations are based on common or distinguishable features within the concepts that are not directly extractable from experience or observed but have to be inferred, for example, by comparative processes such as "high is the opposite of low" or inferences such as "a hammer is tool." These considerations lead to the still-debated question whether and which relations are pre-stored in semantic memory or have to be computed dynamically. Based on empirical research, Klix hypothesized that, in general, inter-concept relations are stored directly in memory, while intra-concept relations are not stored directly in memory but are derived or generated dynamically depending on the respective task demand. Thus, although a direct relation between external and internal representations is naïve, these considerations about internal processes and human memory lead to the question how specific affordances of concept maps may trigger or facilitate internal processes.

Concept maps focus on the visualization of key concepts and key relationships which makes them potentially valuable tools for planning, learning, and (self-)assessment. When used for planning activities, concept maps allow an overview and the detection of the "red line" running through different topics, steps, or key concepts. In learning settings, concept mapping can facilitate organization and elaboration processes leading eventually to the construction of high-level schemas. For assessment, concept maps provide the possibility to tap into a learner's cognitive structure and externalize, for both, the learner and the teacher, what the learner already knows and does not know. However, it is important to keep in mind two limitations of concept maps. First, many learners are initially not familiar with this representation and therefore experience a "lost in the mapping space" phenomenon. This can be described as a feeling of learners being overwhelmed by the unfamiliar representation or confused by the tasks to be carried out. A second limitation is ambiguity: Concepts are usually represented by one or two key words only. Hence, the justifications for certain connections may not be explicit. This limits external judgments, such as scoring or grading procedures that are used to assess the learners' prior knowledge. Negative effects of these limitations may be softened or overcome through self-assessment and prestructuring: In self-assessments learners realize which concepts or relationships they know or do not know yet. The "lost in mapping space" phenomenon may be reduced when the task is prestructured to a substantial degree. However, prestructuring the task too much bares the risk of superficial processing. When provided with a completely worked-out map, learners may not engage in meaningful learning and rather process the material in a superficial mode, which may lead to rote learning. Therefore it seems appropriate to design mapping tasks that leave certain achievable but challenging tasks, targeted at deep-level cognitive and metacognitive processes.

Important Scientific Research and Open Questions

O'Donnell et al. (2002) summarize that concept maps facilitate the recall of central ideas, benefit especially those learners with low verbal abilities and low prior knowledge, and facilitate cooperative learning. Furthermore, they are more effective for learning when structured according to Gestalt principles (e.g., the use of color and shapes to show similarity or groupings to show proximity). The meta-analysis from Nesbit and Adesope (2006) showed a small effect in favor of studying maps compared to studying text, a small effect in favor of studying maps compared to studying outlines or lists, and a small effect in favor of constructing maps compared to constructing text or outlines.

The benefits of concept maps outlined above raise the questions how concept maps should be used for learning and whether elicited cognitive and metacognitive processes are different for different mapping tasks. With respect to the task, concept maps may be created entirely by the student, or instructors can prepare incomplete maps that require learners to perform specific activities, such as filling in some nodes or labeling links. Empirical research indicates that different mapping tasks lead to different cognitive processes (Gurlitt and Renkl 2010). Thus, on a finer level concept mapping has to be differentiated based on the specific tasks left up to the learners. In general, less prestructured mapping tasks lead to more organization processes and provide more flexibility for learners to display their understanding. However, learners may be overloaded with less-structured mapping tasks, and thus they may lead to less elaboration. In addition, less structured maps can be more difficult to interpret for others such as peers or the teacher.

Concluding, it is not enough to assume that concept mapping will automatically facilitate learning. Instead, instructors should consider the relationship between the affordances of the specific mapping task and the focus of the lesson. Tentative recommendations indicate that an active, spatial grouping can facilitate higher-level organization processes compared to just studying the conceptually identical list of concepts. Creating and labeling lines between provided concepts leads learners to focus on organizational aspects of their knowledge, whereas the process of labeling connecting lines on provided relationships can lead to an elaboration of connected concepts.

Cross-References

► Advance Organizer
► Learning Strategies
► Ontology and Semantic Web

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Concept Similarity

► Concept Similarity in Multidisciplinary Learning

Concept Similarity in Multidisciplinary Learning

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Synonyms

Common understanding; Concept map; Concept similarity; Knowledge structure; Multidisciplinary learning

Definition

A *common understanding* can be regarded as the reflection of a shared knowledge structure of a team (Novak and Gowin 1984). A *knowledge structure* on the other hand can be characterized as an elaborated and highly interconnected framework of related concepts (Mintzes et al. 1997). Although there are many different attempts to capture knowledge structures, concept mapping is regarded as a more direct approach and thus has been often used to elicit and represent knowledge structures (Ruiz-Primo 2004).

Concept maps (CMAPs), as a collection of concepts and interconnections among concepts, make knowledge structures assessable. A CMAP is a graph consisting of nodes representing concepts and labeled lines denoting relationships between a pair of nodes. One important characteristic of CMAPs is the expression of propositions, which is represented by using two or more concepts connected by linking words or phrases to convey meaning. Thus, a CMAP can be described as a set of concepts and a set of propositions; accordingly, the *similarity of concepts* can be determined as a function of the propositions.

Theoretical Background

Currently, the mainstream thinking of *multidisciplinary learning* has a clear focus on enhancing collaboration skills of students through team communication (e.g., Fruchter and Luth 2004). On the other hand, studies have shown that the performance of a team also depends on team cognition, of which *team knowledge* is a major component (Cooke et al. 2003). Team knowledge typically includes constructs such as shared mental models representing a common understanding to task procedures, potential constraints, and task strategies. Thus, it is important to understand the relationship between the common understanding of a team and its performance, especially in a computer-mediated environment.

Many researchers have already pointed out that successful collaboration depends on the establishment of a common understanding among students regarding an interdisciplinary subject (e.g., Fruchter 1999). Developing such an understanding is a learning process as well. Consequently, it is important to have a measure that can determine if the knowledge structures of students become similar after some teaching and learning activities.

A traditional test score alone does not provide enough details about the knowledge structure of a student and thus cannot help in analyzing the common understanding of students, especially when learning is mediated by information and communication technologies (ICTs). In a computer-mediated learning environment, quantitatively measuring the similarity of knowledge structures of students can help computers to determine if a common understanding is established among the students. Therefore, such a quantitative measure is critical in terms of assessing the effectiveness of computer-mediated learning.

Although knowledge structures can be represented by CMAPs, which are in the form of graphs, comparing the similarity of multiple graphs is still with great computational complexity, and no reasonable solutions are known. This is the reason that existing graph-based methods are mainly applied to the comparison of two graphs.

To reduce complexity, the similarity of knowledge structures can potentially be determined by measuring the similarity of concepts since concepts are the key component of a knowledge structure. There are many studies on assessing concept similarity and various methods also have been developed, such as the *information content approach*, the *feature-based approach*, the *path distance approach*, and methods based on the *similarity and dissimilarity of description logics*. It is noticed that these methods have their own application requirements and limitations:

1. These methods are typically applied to the similarity analysis of two concepts and their effectiveness for simultaneously analyzing the similarity of more than two concepts is not clearly stated in the exiting literature.
2. Since the triangle inequality property is true to all of those methods, in some conditions, results derived from the methods may not be reasonable if more than two CMAPs are involved.
3. There exists an assumption that the concepts to be compared are in the same structure or graph, especially to the path distance method and the information content method.

Therefore, when comparing multiple concepts represented by independent structures such as CMAPs, it is difficult to measure the path distance between concepts, to only consider is-a relationships, or to limit the analysis to only two concepts at a time. Consequently, there is a need for a different similarity measure.

Important Scientific Research and Open Questions

If we consider the propositions associated with a concept as features of the concept, based on the feature-based method, the *similarity of concepts* can be measured by comparing the propositions of the concepts. Since a CMAP can be described as a set of concepts and a set of propositions. Each CMAP can be used to represent the knowledge structure of a student. Therefore, if there are n students, then there is a set of n CMAPs defined as follows:

$$\mathrm{CMAP} = \{\mathrm{CMAP}_i | 1 \leq i \leq n\} \qquad (1)$$

where CMAP_i = CMAP of the ith student and n = number of CMAPs or students. Each CMAP_i is defined as a pair of concept and associated propositions.

$$CMAP_i = \left\{ \left(c_{ij}, F_{ij} \right) | 1 \leq i \leq n, \;\; 1 \leq j \leq m_i \right\} \qquad (2)$$

where c_{ij} = *j*th concept in the *i*th CMAP; F_{ij} = set of propositions associated with c_{ij}; m_i = number of concepts in CMAP$_i$; and F_{ij} is defined as

$$F_{ij} = \{(p_{ijl}) | 1 \leq i \leq n, \ \ 1 \leq j \leq m_i, \ \ l \geq 1\} \qquad (3)$$

where p_{ijl} = *l*th proposition associated with the *j*th concept in the *i*th CMAP.

To compare concepts from different CMAPs, this study defines a set, S_k, which is a collection of concepts, as well as their associated propositions, selected from different CMAPs for similarity comparisons, i.e., no two concepts in S_k are from the same CMAP. In this way, the comparison of a set of CMAPs is transformed into the similarity analysis of a set of S_k, named as $\overline{S}$. Thus

$$S_k \subseteq \overline{S} \qquad (4)$$

$$S_k = \left\{(c_{ij}^k, F_{ij}^k) | 1 \leq i \leq n, \ \ 1 \leq j \leq m_i, \ \ 1 \leq k \leq w\right\} \qquad (5)$$

where w = total number of concept sets to be compared or $|\overline{S}|$.

An S_k merely regroups the concepts and propositions contained by CMAP. Thus

$$c_{ij}^k = c_{ij} \qquad (6)$$

$$F_{ij}^k = F_{ij} \qquad (7)$$

The total number of propositions associated with the set of concepts, S_k, is defined as

$$N_k = \sum \left|F_{ij}^k\right| (1 \leq i \leq n, \ \ 1 \leq j \leq m_i, \ \ 1 \leq k \leq w) \qquad (8)$$

There are three types of relationships among the concepts in S_k, i.e., identical, similar, and dissimilar. On the other hand, the propositions associated with S_k can be classified into three subsets, *shared*, *overlapping*, and *distinctive*. The shared set contains propositions that are shared by all concepts to be compared. The overlapping set includes propositions that are not shared by all but are shared by at least two concepts. The distinctive set contains propositions that belong to each individual concept and are not shared at all. There are different situations in an overlapping set because a proposition can be shared by two concepts, three concepts, or up to $n - 1$ concepts.

Whether concepts in S_k are identical, similar, or dissimilar is determined by the propositions in the shared, overlapping, or distinctive set. If both the overlapping and distinctive sets are empty and the shared set is not, then the concepts are identical. Concepts are dissimilar if both the shared and overlapping sets are empty and the distinctive set is not. For all other situations, concepts are considered similar.

In the following, formal definitions are given.

Definition 1: A set of concepts in S_k is identical, if and only if, for any F_{ij}^k

$$\bigcap_{i=1}^{n} F_{ij}^k = F_{ij}^k \qquad (9)$$

Definition 2: A set of concepts in S_k is dissimilar, if and only if, for any subset $\hat{S} \subseteq S_k$ ($|\hat{S}| = t, \ 2 \leq t \leq n$), all $c_{ij}^k \in \hat{S}$, and associated propositions, $\hat{F}_{ij}^k$

$$\bigcap_{i=1}^{t} \hat{F}_{ij}^k = \phi \qquad (10)$$

Definition 3: Concepts in S_k are similar, if and only if, (1) there exists at least one $F_{ij}^k (1 \leq i \leq n, 1 \leq j \leq m_i)$, such that

$$\bigcap_{i=1}^{n} F_{ij}^k \neq F_{ij}^k \qquad (11)$$

and (2) there exists at least one $\hat{S} \subseteq S_k$ ($|\hat{S}| = t$, $2 \leq t \leq n$) for all $c_{ij}^k \in \hat{S}$ and associated propositions, $\hat{F}_{ij}^k$

$$\bigcap_{i=1}^{t} \hat{F}_{ij}^k \neq \phi \qquad (12)$$

According to the aforementioned definitions, the similarity of concepts is determined as a function of the three types of propositions. Intuitively, if the number of propositions in the shared set increases and/or the number of propositions in the distinctive set reduces the overall similarity of concepts increases. This study also assumes that the impact of the overlapping set on concept similarity is related to the number and the type of overlapping propositions. For example, if there are four CMAPs, an overlapping proposition may appear in either two maps or three maps. Between these two categories, if the proposition belongs to three maps, its contribution to the overall similarity of concepts is larger.

Thus, the similarity measure, $sim(S_k)$, can be defined as follows:

1. Condition 1: when distinctive = Ø and overlapping = Ø, $sim(S_k) = 1$
2. Condition 2: when shared = Ø and overlapping = Ø, $sim(S_k) = 0$ and
3. Condition 3: when overlapping = Ø or overlapping = Ø but Distinctive ≠ Ø and shared ≠ Ø

$$sim(S_k) = \prod_{i=1}^{n} \left(\frac{i}{n}\right)^{\wedge} \left(i \times \frac{N_i}{N_k}\right) \tag{13}$$

Where n = number of concepts, CMAPs, or students; i = number of concepts that a proposition belongs to; N_i = number of propositions that are shared by i concepts ($2 \leq i \leq n-1$); and N_k = total number of propositions associated with S_k.

Once the similarity of concepts is obtained, this study uses an average method to measure the similarity of CMAPs by aggregating the results of concept similarity analyses. In other words, the similarity of CMAPs is proportional to the similarity of concepts in CMAPs. After a concept analysis, a similarity value is derived for each S_k; thus the similarity of CMAPs is

$$sim\_CMAP = \frac{1}{w} \times \sum_{k=1}^{w} sim(S_k) \tag{14}$$

where w = total number of concept sets in CMAP to be compared for similarity analysis and S_k = kth concept set in CMAP.

The proposed measure is evaluated by (1) comparing it with the Dice coefficient for analyzing two sets of concepts; (2) analyzing its performance in a generic case of four CMAPs; and (3) a case study. Based on initial evaluations, the proposed measure has demonstrated promising features for determining the similarity of multiple knowledge structures or the common understanding of students.

However, there are some areas that need further research. First, when the number of knowledge structures increases, concept similarity analyses become more complicated because uncertain situations arise due to ambiguous human perception to propositions that are shared by multiple concepts. In addition, the proposed method only considers propositions that are immediately associated with concepts to be compared. Sometimes, propositions that are not directly associated with the concepts may also have an impact on similarity analyses. Such an impact is not considered in the proposed similarity measure.

Cross-References

► Concept Formation
► Concept Mapping
► Knowledge Representation

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Conceptual Change

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Synonyms

Change of concepts; Knowledge restructuring; Restructuring of knowledge

Definition

The structure and content of a learners' prior knowledge determines how new information is interpreted and stored in memory. New concepts that are not fully compatible with prior knowledge can, thus, only be learned when the network of prior knowledge is restructured. This process of knowledge restructuring is also referred to as *conceptual change*. Conceptual change can be gradual as well as abrupt and can take various forms. Some of these are the *differentiation* of concepts (e.g., differentiating density from weight), the *coalescence* of concepts (e.g., subsuming solids, liquids, and gasses under a general category of matter), and changes in a concept's *ontological status* (e.g., from weight as a property of an object to weight as a relation between two objects). Conceptual change occurs naturally during a child's conceptual development but can also be elicited and facilitated by means of instructional interventions.

Theoretical Background

The conceptual change approach to learning has roots in the science education research tradition (Posner, Strike, Hewson and Gertzog 1982) as well as in the cognitive-developmental research tradition (Carey 1985). In line with pedagogical constructivism, it emphasizes the importance of prior knowledge and the active role of the learner in knowledge construction. In accordance with cognitive-developmental approaches, conceptual change theories explain developmental phenomena in terms of changes of the underlying knowledge structures. Due to their explanatory and predictive power, for example, regarding students' persistent difficulties and misconceptions, conceptual change perspectives are among the most widely used paradigms in research on science learning and related disciplines.

Basic ideas of research on conceptual change originated from Thomas S. Kuhn's (1922–1996) analysis of the role of paradigm shifts in the history of the sciences. Kuhn emphasized that any change of a scientific paradigm also alters the meaning of the concepts rooted in this paradigm. In the 1980s, educational researchers began to notice the usefulness of this notion for explaining how learners' understanding of a new concept depends on their prior knowledge. Kuhn argued that scientists are likely to substitute an older paradigm with a newer one when specific conditions are satisfied. Posner et al. (1982) argued that a very similar set of conditions determines whether conceptual change takes place in learners. These conditions include (1) a dissatisfaction with existing conceptions, (2) the intelligibility of the new concept, (3) the plausibility of the new concept, and (4) the fruitfulness of the new concepts for explaining observations.

Extrapolating insights from Kuhn's ideas, cognitive-developmental psychologists described cognitive development in terms of the reorganization of initial, domain-specific knowledge structures (Carey 1985). This research strand highlighted the fact that changes in domain-specific knowledge and reasoning are more important driving forces of children's cognitive development than domain-general processes. This challenged older theories, for example, Jean Piaget's (1896–1980) model of four domain-general stages of cognitive development that progress from concrete to abstract thinking. Contrary to this model, research on conceptual change shows that even young children can understand advanced and abstract concepts in a domain where they already have a lot of helpful prior knowledge. At the same time, older children and sometimes even adults can struggle to grasp concrete concepts in content areas where they have incompatible or not enough prior knowledge.

One of the current central theoretical issues in research on conceptual change is the organization of learners' naïve ideas, that is, learners' initial conceptual knowledge structures in a domain. There is a variety of alternative theoretical positions, which can be broadly grouped in two categories: On the one hand, there is the "knowledge as theory" perspective that assumes that initial knowledge structures are theory-like, in the sense of a structure consisting of a relatively coherent body of domain-specific knowledge characterized by distinct ontology and causality, which helps children to understand their environment and make predictions about it (Vosniadou et al. 2008). From this perspective, conceptual change can be described as theory change. The "knowledge as elements" perspective, on the other hand, describes initial knowledge as a loose structure of multiple, quasi-independent elements, which have been acquired in various situations. Only over time and with increasing competence learners start to see their abstract interrelations, thus, constructing more and more integrated knowledge structures (diSessa 2006). Empirical evidence to date is inconclusive with respect to which of the two views is more adequate. The two perspectives agree on the importance of prior knowledge for subsequent learning and on conceptual understanding as based on a complex system of knowledge rather than on single and unitary ideas.

In addition to describing conceptual change in learners, research on conceptual change also investigated how these processes can be influenced by means of instructional interventions (for an overview, see Mason 2001). One central idea is that to achieve conceptual change, a *cognitive conflict* should be elicited in learners, by confronting them with information that contradicts their current state of knowledge. However, several conditions have to be met for a cognitive conflict to be meaningful. Learners have to be motivated to process the anomalous information, they need sufficient prior knowledge to understand the anomalous character of the new information, their epistemological beliefs about the subject matter or about learning and teaching may hinder a revision, and they need adequate reasoning abilities to detect conflict and revise existing knowledge. Despite all these potential difficulties, cognitive conflict is still acknowledged as an important condition which can lead to conceptual change.

There are several ways in which cognitive conflict can be achieved through instruction. One way is to use *refutational texts*, which directly explain common misconceptions and why they are wrong. Another way is through peer collaboration and discussion, since social interaction with peers may promote learners' awareness of their own beliefs and therefore of a possible conflict with new information. The common denominator is that these approaches attempt to develop learners' *metaconceptual awareness*: Learners are not always aware of their presuppositions and beliefs that constrain their learning, and when they are, they do not always understand their theoretical or contradictory nature, or that they are open to falsification.

A further important approach is the use of analogies. Analogical reasoning, in particular, cross-domain mapping, has been shown to play a major role in restructuring learners' existing knowledge. This is because the comparison between two domains may highlight their common features and reveal unnoticed commonalities, and foster the projection of inferences from the more familiar domain to the other. This could lead to conceptual restructuring in the target domain. Closely related to analogies, the role of providing adequate models or external representations has been shown as important in promoting conceptual change, because these models and representation can be used to clarify aspects of a scientific explanation that are not apparent in other models.

Yet another implication of conceptual change research relates to the curriculum and the way in which it is organized. If certain concepts in science and mathematics are particularly difficult and give rise to misconceptions, it may be more profitable to focus more deeply on a limited number of topics rather than superficially dealing with many topics. Moreover, the order in which concepts are dealt with should be carefully considered in order to avoid certain misconceptions.

Important Scientific Research and Open Questions

In order to analyze the content and structure of learners' conceptual knowledge in scientific domains and how these structures change over time, conceptual change researchers typically conduct interviews. For example, Vosniadou and Brewer (1992) asked various first-, third-, and fifth-graders questions about the shape of the earth, such as "Can you draw a picture of the earth?" or "If you walked for many days in a straight line, where would you end up?" They categorized children's answers as indicating one of six alternative mental models of the earth. There was a clear age trend leading away from more naïve conceptions (e.g., the earth as a flat square) over several conceptions mixing naïve and scientific ideas, toward more scientifically correct concepts (the earth as a sphere) with increasing age. The answer patterns could be interpreted in terms of conflicts between new information about the earth as a sphere and children's prior knowledge that the ground they stand on appears to be flat and that objects fall from underside of a sphere in everyday life. This study is paradigmatic for many subsequent studies with a similar methodology, that is, interviews with children of different ages about their physics concepts.

Although interview methods are still used in most studies on conceptual change, there is a growing awareness of the importance of complementing them by alternative approaches. Interviews yield only very indirect evidence of mental knowledge structures. Category systems for interview data are always arbitrary and can, thus, lead to contradictory results. Cross-sectional age-group comparisons do not allow for the investigation of individual developmental pathways of conceptual change. Therefore, researchers are currently exploring how to complement these traditional approaches by alternative methods, either to unravel underlying reasoning processes (e.g., by using eye-tracking data and reaction time measures) or to reveal learners' individual developmental pathways of conceptual change (by using longitudinal designs). Written tests containing several items targeting the same concept from slightly different angles might be helpful for assessing gradual changes in how strongly a person adheres to this concept. Finally, latent variable analyses are used to account for the indirect relation between overt behavior and the underlying knowledge structures.

In recent years, research has also taken into consideration further factors that influence conceptual change learning, in addition to cognitive ones. For example, the term *hot conceptual change* has been used to emphasize this importance of the learner's motivation and intentions for conceptual change. Likewise, learner's *epistemological beliefs* of the nature of knowledge, the nature of learning, the nature of scientific evidence have been shown to crucially determine how learners' perceive and regulate their own conceptual change.

Finally, the mechanisms of conceptual change are not only relevant for science learning but whenever learners acquire complex knowledge structures. There is research on conceptual change in physics, biology, medicine, and history, and several other domains. Recently, the conceptual change approach has also been extended to mathematics. This might seem surprising, because mathematics is a formal content domain with clearly defined concepts, where children's naïve theories and everyday life experiences might play little role. However, empirical research shows that the opposite is true. For instance, when children try to understand fractions, they struggle with their prior knowledge about the nature of numbers, infinite divisibility, successor relations, and so on. These implicit assumptions might have been acquired with objects in everyday life or with whole numbers and hinder the understanding of fractions.

Cross-References

► Analogy-Based Learning
► Categorical Learning
► Cognitive Conflict and Learning
► Cognitive Models of Learning
► Constructivist Learning
► Deep Approaches to Learning in Higher Education
► Epistemological Beliefs and Learning
► Human Cognition and Learning
► Learning and Understanding
► Learning with External Representations
► Role of Prior Knowledge in Learning Processes
► Simulation and Learning: The Role of Mental Models

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Conceptual Clustering

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Synonyms

Learning from observation; Symbolic clustering

Definition

A clustering algorithm is one that takes a collection of entities and divides them into a set or hierarchy of groups based on some predefined preference criteria. Conceptual Clustering refers to those clustering algorithms that largely select their groupings based on the quality of the resulting concept descriptions. Thus, it is not sufficient that the entities in each group generally display similarity to one another, and dissimilarity to those in other groups; the groups should also have understandable descriptions that characterize their membership. Michalski and Stepp (1983) defined the process of conceptual clustering as creating "classifications in which a configuration of objects forms a class only if it can be closely circumscribed by a conjunctive concept involving relations on selected object attributes." Each class should be disjoint from others and optimize a quality criterion, which may be a simple criterion or a more complex selection specification.

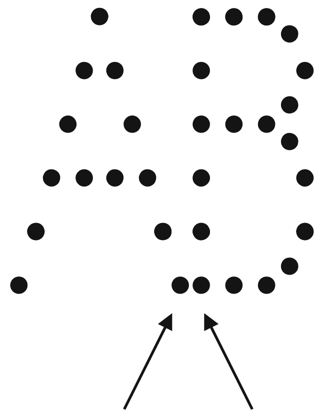
Theoretical Background

Conceptual clustering attempts to divide input entities into groups that will be meaningful to the user and useful for future tasks. It is an unsupervised method, that is, there is no "oracle" to determine the "correctness" of the classifications. Therefore, it belongs to the "learning from observations" class of methods.

Traditional clustering methods work best on attributes with ordered attribute domains, in which one can measure and compare distances between pairs of values of an attribute. In such algorithms, an entity will typically be grouped with those that are very "close" to it. In unordered (categorical) attribute domains, where the proximity relationship is replaced by a Boolean equality relationship, numerical clustering has more difficulty in determining useful groupings.

In conceptual clustering on the other hand, criteria other than proximity have a large effect on the placement of an entity. The other entities in the group are considered, and it is vital that a high-quality concept description characterizes the group (Michalski 1980; Fisher and Langley 1986). Entities are grouped together if they belong to the same concept, even if physically located "far" from each other.

To illustrate the difference, consider the points in Fig. 1 and the task of dividing them into two groups. A traditional clustering method would likely place the two points indicated by the arrows into the same group, as they are the closest ones to each other in the figure.



Conceptual Clustering. Fig. 1 An illustration of the value of concepts in clustering

On the other hand, a human presented with the same task would likely place them into different groups, because the groups created would conform to the simple concepts: points that form the letter A and points that form the letter B. A conceptual clustering program given the appropriate background knowledge could make a similar classification.

Conceptual clustering algorithms generally create hierarchies of classes, and may build them in top-down or bottom-up manners. In the former, the set of objects is divided into a small number of classes, each of which may be divided into subclasses, iterating until a termination condition is met. In bottom-up clustering, each object is initially considered to be in its own class; they are then grouped together, and the resulting groups are then brought together into superclasses, until the top level is reached. Another form of clustering algorithm is incremental, meaning that it analyzes examples one at a time, creating and modifying classes based on the new information.

Among the pioneering programs for conceptual clustering are the CLUSTER series (e.g., Michalski and Stepp 1983), UNIMEM (Lebowitz 1987) and COBWEB (Fisher 1987). These programs have been applied to such diverse areas as creating classifying hierarchies of plant diseases, Spanish folk songs, and taxpayers for the purpose of compliance enforcement.

Important Scientific Research and Open Questions

A major advantage of conceptual clustering in comparison to traditional clustering methods is the way in which its classifications closely reflect how we ourselves would classify groups of entities. Accordingly, an inviting area for further research is the further modeling of how humans group objects and developing the means to implement such models into conceptual cluster selection criteria. In general, the ability to take advantage of available background knowledge will allow the clustering algorithm to select groupings with meaningful concept descriptions.

Cross-References

► Classification of Learning Objects
► Concept Formation
► Learning task(s)
► Observational Learning
► Unsupervised Learning

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Conceptual Configurations

► Representations, Presentations, and Conceptual Schemas

Conceptual Conflict

► Cognitive Conflict and Learning

Conceptual Dependency Structure

The basic assumption of conceptual dependency theory (Schank 1975) is the idea that conceptualizations can be represented in terms of a small number of primitive acts performed by an actor on an object. Conceptualization attribute cased to actions: Actor, object, recipient, direction, state (of an object), and instrument. The various cases can be filled through individuals that belong to corresponding concept categories (and a vocabulary). The important categories are

- ACT is the action which occurs,
- Picture Producer as totality of all physical objects (e.g., actor and recipient),
- LOC, i.e., the location where ACT occurs;
- Time, i.e., the point of time when ACT occurs;
- Picture aider, i.e., the current state of the Picture Producer.

ACTs are primitive actions that are at the core of conceptual dependency. Schank (1975) has defined eleven primitive actions (e.g., propel, move, speak, attend, ptrans) from which all verbs of natural language can be derived by means of combinations. Additionally, there is a number of causal relations (such as reason, result, and enablement) to link the ACTs with each other.

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Conceptual Framework

► Advance Organizer

Conceptual Graphs

► Semantic Networks

C

Conceptual Growth

► Deep Approaches to Learning in Higher Education

Conceptual Maps

► Concept Maps

Conceptual Model of School Learning

► Bloom's Model of School Learning
► Carroll's Model of School Learning

Conceptual Representations

► Representations, Presentations, and Conceptual Schemas

Conceptual Structures

► Representations, Presentations, and Conceptual Schemas

Conceptualization

► Models and Modeling in Science Learning

Conclusion by Analogy

From a logical point of view, analogy – or more precisely, the relation of analogy – is the product of a conclusion by analogy, which has been defined as follows: If two species, S_1 and S_2, of a genus M show the same behavior, i.e., if there is an attribute Q for which "'all S_1 are P' and 'all S_2 are P' are true (*tertium comparationis*), it is then possible to conclude 'all S_2 are P' from 'all S_1 are P' by analogy, provided that 'all Q are P' is true." Consider the following simple example: Let M be the family of quadrangles, S_1 a rectangle and S_2 a rhombus, and Q the attribute that the opposing sides have the same length. As you know, this attribute is shared by all rectangles and rhombi. Thus, all S_1 have the attribute Q *and* all S_2 do as well. If it is stated that a rectangle is a parallelogram by virtue of this attribute, then the statement is also true that a rhombus is a parallelogram.

Concrete–Abstract Objects and Cognition

► Cognitive Artifacts, Technology, and Physics Learning

Concurrent Discrimination Learning

► Learning Set Formation and Conceptualization

Conditional Association

► Conditional Reasoning by Nonhuman Animals

Conditional Discrimination

An experimental procedure in two or more discriminative stimuli is presented on each trial and which stimulus is designated as correct changes depending on the stimulus context. The matching-to-sample procedure is an example of a conditional discrimination: Which comparison stimulus is correct on a given trial depends on which sample stimulus was presented.

Cross-References

▶ Matching to Sample Experimental Paradigm

Conditional Discrimination Learning

▶ Conditional Reasoning by Nonhuman Animals

Conditional Effects

In the context of statistical analysis, a conditional effect occurs when the relationship between an independent variable and a dependent variable depends on the specific value of a third variable.

Conditional Knowledge

This conception describes knowledge about the context and influencing factors of a certain issue, i.e., when and how to use which procedure or skill (and when not to use it). As such, it is often crucial for applying knowledge and skills successfully in practice.

Conditional Reasoning by Nonhuman Animals

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Synonyms

Conditional association; Conditional discrimination learning; Conditional rule learning; if–then reasoning; if–then rule learning; Logical reasoning; Relational concept learning

Definition

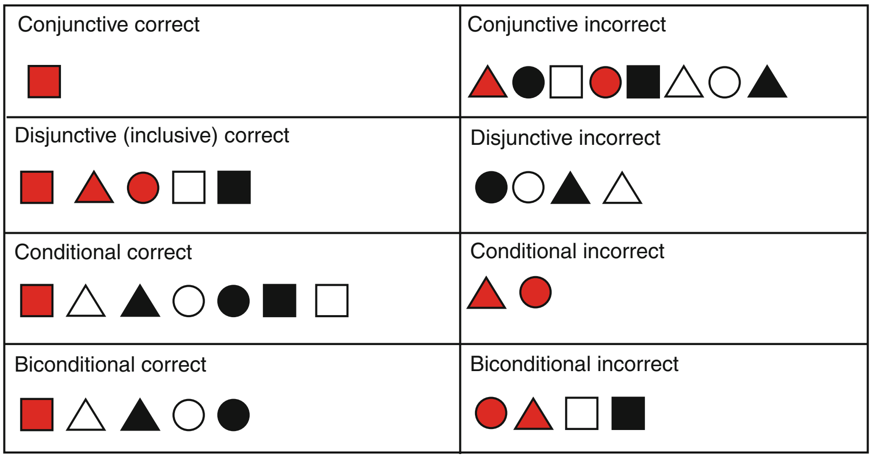
Conditional reasoning (*conditional association* or *conditional rule-learning* might be better terms) means that, when performing complex tasks, animals should partition discriminanda consistent with the truth-table manifestations for the conditional in symbolic logic (see example below). Conditional reasoning is representative of relational concept learning at the next-to-highest level of intellectual capabilities based on Thomas's approach to assessing animal intelligence (e.g., Thomas 1980; Bailey et al. 2007).

Theoretical Background

It is generally accepted in the human concept learning literature that a nonverbal, experimental demonstration of conditional reasoning must result in the partitioning of discriminanda consistent with the truth-table manifestations specified for those discriminanda by the conditional in symbolic logic (Bourne 1970). Attending first only to the bold print letters and symbols in the truth-tables below, consider both the conditional and the conjunctive, because all known experiments using nonhuman animals have confounded conjunctive and conditional reasoning as potential explanations for successful performances.

Conjunctive			Conditional		
p	Q	p and q	p	q	p > q
T red	**T** square	**T** correct	**T** red	**T** square	**T** correct
T red	**F** not-square	**F** incorrect	**T** red	**F** not-square	**F** incorrect
F not-red	**T** square	**F** incorrect	**F** not-red	**T** square	**T** correct
F not-red	**F** not-square	**F** incorrect	**F** not-red	**F** not-square	**T** correct

Truth-tables are abstractions. To adapt them for experimental research, Bourne (1970) used discriminanda that varied in color and form. Referring again to the truth-tables and using red and square as focal attributes, substitute red when **p** is **T** and not-red when **p** is **F** and substitute square when **q** is **T** and not-square when **q** is **F**. Regarding partitioning outcomes, beneath **p** and **q** or beneath **p** > **q**, read **T** as denoting a "correct" partition and **F** as denoting an "incorrect" partition according to contingencies for each row in the truth-tables. As may be seen in the truth-tables and in the illustration below (adapted from Bourne), the only correct partition for the conjunctive is when the object is a red-square. For the conditional, the only incorrect



Conditional Reasoning by Nonhuman Animals. Fig. 1 Correct and incorrect assignments according to conjunctive, disjunctive, conditional, and biconditional rules when Red and square are focal attributes

partitions are red objects that are not-square; no conditions are specified for being incorrect when **p** is not-red. In Bourne's (1970) research, subjects had to infer which truth-table was applicable based on experimenter feedback, such as, saying "correct" or "incorrect" according to whether the discriminanda were being partitioned consistently with a given truth-table's contingencies. The illustration also shows how discriminanda must be partitioned according to conjunctive, disjunctive, conditional, or biconditional truth-tables when red and square are the focal attributes.

There is an extensive history of investigating "conditional discrimination learning," "conditional rule learning," "if–then rule learning," etc., by nonhuman animals using various procedures, and often it is stated or implied that the animals had demonstrated conditional reasoning corresponding to forms such as, "if **p**, then **q**." However, this article questions whether there has ever been a valid demonstration of conditional reasoning by nonhuman animals.

Previous investigators used methods that either (a) confounded conditional reasoning with the possibility of rote-memorization or (b) confounded the possibility of conditional reasoning with conjunctive reasoning. The only nonverbal procedure of which I am aware that might be used to show unequivocal conditional reasoning by an animal was developed for use with humans. However, that experiment appears to be impractically difficult for nonhuman animals, and its author (Bourne 1970) relied partly on the subjects' verbal explanations to confirm how they had reasoned. It is hoped that one result of the present article will be to prevent future researchers from misinterpreting or misrepresenting, either inadvertently or intentionally, the results of typical conditional-discrimination, rule-learning research using nonhuman animals.

Important Scientific Research and Open Questions

The typical conditional learning task used with nonhuman animals involves two successively presented discriminanda, represented here as A and B, only one of which is presented on a given trial, and two simultaneously presented discriminanda, represented here as X and Y, which appear on every trial. A or B serves as an associative cue to select either X or Y. It is tempting to describe and conceptualize such tasks, as many investigators have done, as embodying conditional reasoning such as: "If A, then X and if B, then Y."

Typically, relatively few discriminanda are used and they are presented more than once. Repeated presentations make it likely that the relatively few specific configurations afforded by the discriminanda might be learned by rote-memorization. As others have noted, such configuration learning is confounded with the *possibility* that the animals used conditional reasoning. However, such confounding prevents such studies from providing conclusive evidence for conditional reasoning by animals. Even if specific configuration learning is precluded, there remains a fundamental problem that all known experiments using animals have confounded the possibility of conjunctive with conditional reasoning.

There are three basic ways to avoid specific configuration learning: (a) use exemplars from conceptual categories for the successive discriminanda, (b) use exemplars from conceptual categories for the simultaneous discriminanda, or (c) use exemplars from conceptual categories for both the successive and simultaneous discriminanda. Burdyn and Thomas's (1984) investigation will illustrate both the use of conceptual categories as discriminanda and how conjunctive and conditional reasoning are confounded.

Burdyn and Thomas (1984) used exemplars of the conceptual categories "same" and "different" as the simultaneous discriminanda; an exemplar of "same" was an identical pair of objects and an exemplar of "different" was a nonidentical pair of objects. *New* pairs of objects were used on each trial in the conceptual category phases of the testing which precluded the monkeys from memorizing specific discriminanda and reinforcement associations. The successive discriminanda involved the conceptual categories "triangularity" and "heptagonality" which were represented by using 120 discriminable triangles and 120 discriminable heptagons. Such a large number of discriminanda together with trial-unique exemplars of "same" and "different" made it unlikely that the monkeys memorized and associated specific triangles and heptagons with same and different.

An apparatus with three guillotine doors was used. During most of the training, all three doors were raised and lowered concurrently. On a given trial, (a) either a triangle or a heptagon appeared as the center door was raised, (b) a pair of identical objects appeared as a result of raising one of the outer doors, and (c) a pair of nonidentical objects appeared as a result of raising the other outer door; the choice of triangle or heptagon and the left-right locations of the same and different pairs were determined quasi-randomly for each trial. When a triangle was presented, the correct response was to displace the object-member of the same-pair that was closest to the center door; doing so revealed a food well with a bit of fruit reinforcement beneath the object. When a heptagon was presented, the correct response, similarly reinforced, was to the object-member of the difference-pair that was closest to the center door.

In the final stage of training, the center door was raised to expose either a triangle or a heptagon; then, it was closed to cover the triangle or heptagon before the outer doors were raised to expose the same and different pairs of objects. Intervals between closing the center door and concurrently raising the outer doors were increased systematically. The best performing monkey met a stringent criterion of correct responding (13 of 15 correct on 15 triangle-same trials and 13 of 15 correct on 15 heptagon-different trials within a 30-trials session) with a 16 s. interval. Therefore, when the successive cues were visually absent, "triangularity" and "heptagonality" had to be retained symbolically in working memory as cues for "same" and "different," respectively.

It is tempting to conceptualize the monkeys' successful performances as conditional reasoning which might be expressed as "*if* triangle, *then* same" and "*if* heptagon, *then* different." However, Burdyn and Thomas realized that they could not conclude that unequivocally, because it was also possible that the monkeys were reasoning *conjunctively* such as "triangle *and* same" and "heptagon *and* different." This general interpretational problem appears to have affected all other so-called conditional rule-learning studies in animals. It should be noted also that most animal studies have *not* used conceptual-category discriminanda which means their subjects might have memorized the specific configurations associated with the discriminanda-reinforcement contingencies.

Bourne (1970) also realized that his subjects might have performed on some basis other than implementing the requirements of the appropriate truth-table, but he was able to determine through a series of transfer experiments that his subjects had learned the rules. Some of the transfer experiments involved the experimenter and the subjects discussing the applicable rule. It is unlikely that such verbal validation will be available to animal researchers, and it remains to be seen whether animals will show the kind of perfect or near-perfect transfer of training that is necessary otherwise to confirm that the subject reasoned conditionally. By "near-perfect," it is meant that there must be so few mistakes that the subject likely could not have memorized specific discriminanda and reinforcement relationships.

A minimum of four trials is necessary merely to present the minimal information to show which rule is operating, namely, one trial each to manifest each row contingency in a given truth-table. After being trained on a succession of problems based on the same logical operation, Bourne's human subjects learned to use the four informational trials to attain thereafter perfect or near-perfect performances on new problems. Presumably, this could be done only if the subjects had inferred correctly and followed the appropriate truth-table.

Future animal research on conditional reasoning can and must be improved by precluding the possibility of rote-memorization of the discriminanda or configurations of the discriminanda. This is best done by using conceptual-category discriminanda. Response contingencies that allow the subject to affirm or negate exemplars might be helpful. If animal experiments are based on Bourne's procedure, they would involve reinforcing an animal's responses that correctly affirmed or negated each discriminandum in accordance with the applicable truth-table. A series of problems should be administered according to a single operation, until, following the administration of the four mandatory, informational trials on *new* problems, the animal continued with perfect or near-perfect performances, or until it seemed unlikely that the animal would be able to attain such performances. If perfect or near-perfect performances were seen on new problems, it should be reasonable to attribute the use of the conditional reasoning to the animal (or conjunctive reasoning, etc., depending upon which truth-table was being applied).

This article would be incomplete without acknowledging that some scholars have tried to reconcile standard logic with what some refer to as "natural" or "mental logic" (e.g., Braine and O' Brien 1998). Such logic is said to apply to cases of reasoning that reflect genuine, "if–then" conditional reasoning without using procedures that fulfill the requirements of the truth-table for the conditional. However, consideration of natural versus standard logic has not revealed how the methods associated with natural logic will enable us to design experiments to distinguish how animals may have reasoned. Thus, it appears that the most conservative and justifiable approach is to continue to attempt to investigate animals' use of the conditional reasoning based on methods that embody truth-functional logic.

Cross-References

▶ Abstract Concept Learning in Animals
▶ Animal Intelligence
▶ Associative Learning
▶ Categorical Learning
▶ Complex Learning
▶ Complex Problem Solving
▶ Concept Learning
▶ Conditional Reasoning
▶ Conditions of Learning
▶ Discrimination Learning Model
▶ Evolution of Learning
▶ Inductive Reasoning
▶ Laboratory Learning
▶ Logical Reasoning and Learning
▶ Measures of Similarity
▶ Nature of Creativity
▶ Problem Solving
▶ Rote Memorization

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Conditional Rule Learning

▶ Conditional Reasoning by Nonhuman Animals

Conditioned Avoidance

▶ Aversive Learning in Drosophila melanogaster

Conditioned Inhibition

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Synonyms

Inhibitory conditioning

Definition

A conditioned inhibitor conveys information that a possible future event is less likely than it would be otherwise. In a conditioning experiment, the presence of an inhibitory conditioned stimulus (CS−) may identify the trials on which an excitatory conditioned stimulus (CS+) will not be followed by the unconditioned stimulus (US). In the real world, a patient may be encouraged to use a talisman as a safety signal that no harm will occur outside the therapist's office.

Theoretical Background

Some of what we have previously learned may not be applicable in other places and at other times. Perhaps the best studied example of this caveat is conditioned inhibition, a term introduced by I. P. Pavlov (1927) to describe the objective circumstances and mechanistic processes involved in the suppression of a well-conditioned behavior. In one classical conditioning experiment, he taught a hungry dog to salivate at the sound of a beating metronome (the CS+) by having it signal the delivery of food (the US), and to withhold responding when the signaling metronome was accompanied by the illumination of a light (the CS−) without food presentation (unreinforced). His discovery of this unreinforced compound method is the objective circumstance most closely identified with the term conditioned inhibition, although there are other methods leading to the same result. Motivated by his background as a physiologist, Pavlov inferred that a counteracting internal force must have gradually dampened the generalization of the learned behavior from the metronome-alone trials to the compound metronome-light trials. In particular, the light seemed to have acquired inhibitory properties which gradually came to suppress activation in cortical areas of the dog's brain normally excited by the sound of the metronome. Nowadays, the concept of conditioned inhibition is still closely tied to neural inhibition, which suggests a fundamental soundness in his thinking. The difference is rather than interrupting, reducing, or blockading the transmission of a neural message, a change in a publicly observable behavior is the ultimate criterion for the existence of conditioned inhibition.

Under what situations does conditioned inhibition develop, how is conditioned inhibition best assessed, and what is the underlying mechanism? In addition to the standard method involving unreinforced compound trials, it seems that any circumstance in which a prior expectation is not fulfilled is the key to the development of conditioned inhibition (Wagner and Rescorla, 1972). Some examples include:

- Omitting the US after a well-trained CS+ in experimental extinction
- Reinforcement of CS+, and nonreinforcement of CS–, on separate trials in differential conditioning
- Introducing the US before the CS in backward conditioning
- Slowly extending the time delay from CS onset until US delivery in inhibition of delay

It is worth mentioning that many other factors are known to influence the effectiveness of these methods (LoLordo and Fairless 1985). Furthermore, the preceding list does not include all procedures that may lead to conditioned inhibition.

What brain mechanisms are engaged by the unexpected absence of the US in a conditioning experiment? One of the most intriguing recent findings in neuroscience is the discovery of dopaminergic neurons in the reward system of monkeys which seem to encode the surprise value of the US. These midbrain neurons respond vigorously when unexpected juice US is first delivered. Over trials, this initial neural response diminishes as the animal learns the CS-US relationship, and is presumably no longer surprised at US delivery. Interestingly, the surprising absence of the US on a test trial is registered as a decline in neural activity at the exact time the US would normally have been delivered. Thus, the unfulfilled expectation of the US on a test trial is revealed as a change opposite to the surprising occurrence of the US (Tobler, Dickinson, and Schultz, 2003).

The proper assessment of conditioned inhibition has long been a contentious issue. Some of this controversy revolves around what treatments should serve as a control for experience with the CS and US, and the relationship between them. It is both convenient and theoretically meaningful to regard the signaling power of a CS as falling somewhere on a scale from +1.0 (excitor) to −1.0 (inhibitor) with a zero neutral point. The best control treatment then would theoretically leave the control CS with zero signaling power. One possibility might be to schedule the control CS at random times during the experimental session. Unfortunately, chance forward pairings of the control CS with the US can sometimes lead to elevated responding, leaving the neutrality of the control CS in question. Any alternative procedure in which one of the two main players in the relationship is omitted, the CS or the US, is difficult to defend. This state of affairs has led to the tailoring of control procedures to suit the experiment at hand. For example, if arbitrary letters are used to stand for which of several possible conditioned stimuli in the experiment are actually present on a given trial (A, B, C...), and the presence ("+") or absence ("−") of a subsequent US is indicated, the compound trial method can be denoted as A+, AB−. Here, B is the conditioned inhibitor. Accordingly, we might schedule A+, AB−, and C− trials in the experimental group, and A−, AB−, and C + trials in the control group. In theory, B should be more inhibitory in the experimental group than in the control group because it clearly signals the omission of an otherwise expected US (evoked by A). However, it is possible the intermixing of trials in the A−, AB−, C+ control arrangement could also lead to some inhibition as AB− is differentiated from C+. This has led to the adoption of multiple control procedures in some experiments, none of which on its own is the single best.

Historically, the most troublesome aspect of the assessment question is how best to distinguish between a subject curtailing an otherwise likely response and simply not responding. The general approach has been to insist the inhibitor show the ability to suppress responding evoked by another known excitor (summation test), as well as to show the inhibitor is not easily converted into a signal for the presence of the US (retardation test). By providing an alternative impetus for responding, both tests create a nonzero response baseline which allows a negative tendency to be distinguished from simply not responding at all. The introduction of the two-test strategy by Rescorla (1969) provided a solid foundation for a rich set of later experimental findings in an area largely dormant since Pavlov's original observations.

One of these new findings is that conditioned inhibition is mediated by multiple mechanisms. Some conditioned inhibitors seem to cancel a US expectation that evoked a specific CS (negative occasion setter) but not all other CSs (standard conditioned inhibition). Conditioned inhibitors in the former class reduce the behavioral effects of the specific excitor they previously accompanied, but less so a new excitor in a summation test. The negative occasion-setting mechanism seems to be favored when the inhibitory CS on the trial terminates shortly before its excitatory partner is nonreinforced. Situational or apparatus cues are also more likely to act as negative occasion setters than conditioned inhibitors. A short list of other generally agreed characteristics of conditioned inhibition are:

- Learned expectations must be acquired before they can be suppressed by conditioned inhibition.
- Conditioned inhibition is less well retained than conditioned excitation over a retention interval.
- A CS− will not lose its inhibitory power when unreinforced in isolation outside of the original unreinforced compound.
- Instrumental actions can serve as conditioned inhibitors in avoidance learning. Here, the action signaling that a potentially aversive event will not occur serves as the inhibitory stimulus.
- Conditioned inhibition develops whenever an expectation of the forthcoming US is greater than the US actually obtained on the trial; hence, two excitors previously trained on separate trials will lose associative strength if they occur in compound and are actually followed by the US (overexpectation).
- A neutral stimulus reinforced in the presence of a conditioned inhibitor will gain strength extraordinarily quickly because of the larger than normal discrepancy between the subject's "negative" expectation and the delivery of the US on the trial (supernormal conditioning).

- An excitatory CS can be protected from extinction if it is accompanied by a conditioned inhibitor when nonreinforced.
- Conditioned inhibitors sometimes, but not always, convey information about the omission of a particular identifiable event, such as the absence of sugar-water but not the absence of food.

Important Scientific Research and Open Questions

Some of the properties of conditioned inhibitors remain open to question. Researchers have reported that extensive extinction of the particular CS+ associated with the CS− can eliminate conditioned inhibition. The conditions under which such deactivation occurs continue to be studied (Urcelay and Miller 2006). Another question of continuing interest is to what degree inhibitory conditioning plays a role in human causal inference. Is a preventative cause just an inhibitory signal that an expected effect will not occur? Much applied research has been directed at enhancing the effectiveness of extinction (conditioned inhibition) to dampen traumatic memories. Can pharmacological agents be used to both quicken the process of extinction and make it stick in new contexts? Alternatively, does fast extinction simply create the conditions for response recovery? Finally, do unreinforced trials given in the short temporal window after acquisition prevent consolidation of a freshly learned CS-US association?

Cross-References

► Associative Learning
► Avoidance Learning
► Computational Models of Classical Conditioning
► Conditioning
► Contingency in Learning
► Extinction Learning
► Human Causal Learning
► Inhibition and Learning
► Learning Not to Fear
► Pavlov, Ivan P.
► Pavlovian Conditioning

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Conditioned Response

When the pairing of one stimulus with another results in some specific change in response to either stimulus, then that change can be identified as having a conditioned basis. The oft-cited example of a conditioned response is Pavlov's serendipitous observation that hungry dogs will come to salivate to a bell that has previously signaled the delivery of food.

Conditioned Sensitization

► Drug Conditioning

Conditioned Stimulus (CS)

This is a stimulus that, owing to its having appeared repeatedly and anticipatedly upon arrival of an unconditioned stimulus (US), its mere presence ends up triggering a response similar to that of the US. For example, the sound of the dentist's drill triggers the anticipatory anxiety of the pain caused by the contact with the dental nerve.

Conditioned Suppression

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Synonyms

CER (Conditioned Emotional Response)

Definition

Like many terms in the field of learning, ► conditioned suppression is defined jointly in terms of a procedure and a result. The procedure involves pairing a relatively neutral stimulus, such as a change in ambient noise or illumination, with a relatively aversive stimulus, such as mild electric shock. The result is that a subsequent presentation of the previously neutral stimulus suppresses the rate of an ongoing behavior. In most research, the subject of the experiment is a food- or water-restricted laboratory rat, the shock is delivered through a grid floor in the conditioning chamber, and the ongoing behavior consists of pressing a lever for food or licking a filled water bottle. The reader will notice immediately that the conditioned suppression procedure is a Pavlovian one in that it involves the pairing of a relatively neutral stimulus (the to-be-conditioned stimulus, CS) with a non-neutral stimulus (the unconditioned stimulus, US). The result is the Pavlovian result – a change in the behavior evoked by the CS.

Theoretical Background

Conditioned suppression was first demonstrated by Estes and Skinner (1941). About 10 years later, its popularity as a research tool began to soar, probably because it provided a vehicle for studying Pavlovian conditioning without requiring the surgical skill of Pavlov or the use of dogs, and because it produced orderly and robust results. Certainly, most of the phenomena that Pavlov demonstrated with his salivary conditioning procedure have been replicated with the conditioned suppression procedure. More importantly, the procedure became one of the more popular tools for testing theories of learning. Among the major theoretical issues addressed using the procedure in the last 40 years are the role of CS-US contingency versus contiguity in Pavlovian conditioning and tests of comparator theory and of computational models of learning.

Estes and Skinner (1941) entitled their paper "Some quantitative properties of anxiety." So from the start, it was thought that conditioned suppression reflected learned anxiety or fear. For this reason, the procedure is often called the conditioned emotional response (CER) procedure. If conditioned suppression truly reflects learned anxiety or fear, then the suppression technique should offer an excellent animal model for the study of the acquisition and hopefully the elimination of learned anxiety disorders in humans. Much recent research has been directed toward this end (e.g., see Thomas et al. 2005 and citations therein).

There are two techniques for demonstrating conditioned suppression. In the on-line technique, each CS-US pairing is superimposed upon the ongoing or baseline behavior. In the off-line technique, CS-US pairings are given in the absence of the ongoing or baseline behavior. Later, one or more CS-alone trials are superimposed upon that behavior to allow suppression to be measured. Each technique has important advantages and disadvantages.

The main advantage of the on-line technique is that it allows performance on every CS trial to be observed. The disadvantage is that each time the US is paired with the CS, it is also paired with the context (the chamber that contains the subject). To the extent that the context evokes suppression in CS absence, measurement of suppression to the CS itself is complicated. In the extreme, if suppression evoked by the context is complete, no suppression to the CS can be measured. This problem can be mitigated by appropriate spacing of CS-US pairings. The spacing needs to be great enough to allow suppression to the context to extinguish between pairings.

If the acquisition process itself is not of interest, the CS-US pairings can be given off-line. Since no suppression can be measured during acquisition with the off-line technique, many CS-US pairings can be given in a single session. Later, the CS can be superimposed on ongoing behavior in a new context, and suppression to the CS can be measured without complication from suppression evoked by the test context. An alternative to changing the context is to insert "recovery" sessions between acquisition and test. Such sessions allow the ongoing behavior to occur unimpeded by programmed

CSs or USs and promote extinction of suppression to the context. The experimenter can see if the ongoing behavior rate is adequate for testing the CS, and, if so, can measure suppression to it in a subsequent session. Off-line conditioning procedures also allow the use of short CSs (except on test trials) if that is desired. CS durations of 1–15 s. are common. In contrast, with on-line techniques, the CS must be long enough to permit a reliable measure of the ongoing behavior in its presence. So in the on-line procedure, CSs are typically 1–3 min. in duration.

A danger in using off-line techniques arises when the experiment requires complex procedures and multiple phases. When these phases are conducted off-line before an ultimate test trial, the experiment can resemble a magic act. The audience sees the magician pull the rabbit out of the hat on the test trial but can only guess how the rabbit got there. In contrast, a similar experiment conducted on-line is fully transparent (for a discussion of this issue, see Rauhut et al. 2000, pp. 106–107).

Important Scientific Research and Open Questions

A criticism of conditioned suppression is that it tells us what the subject is *not* doing during the CS (it is not engaging in the ongoing or baseline behavior), but it does not tell us what the subject *is* doing. If Estes and Skinner were correct in assuming that conditioned suppression reflects fear, then we should be able to predict what the animal actually does during the CS. A basis for such a prediction is an observation by Fanselow and Lester (1988), who noted that fear restricts an animal's behavior to a small number that have an evolutionary history of thwarting predation. They stated that in the laboratory rat, the most dominant of these behaviors seems to be freezing or defensive immobility. Usually, but not always, freezing occurs in a crouched position.

A number of studies have directly observed behavior during conditioned suppression and have systematically measured freezing (e.g., see Kim et al. 1996 and citations therein). They have found that freezing does indeed occur during the CS and that the degree of suppression is correlated with the degree of freezing. (Freezing was defined as the absence of any movement save that of the sides needed for breathing.) Interestingly, Kim et al. found that freezing was not the whole story of conditioned suppression, because subjects froze more to tone CSs than to light CSs even though suppression to each was equal. They then conducted a series of assays designed to see if learning was weaker to light than to tone, but that did not appear to be so. Finally, they arranged for suppression to be weaker to tone than to light but still found more freezing to tone. The results suggest that conditioned suppression may be a more sensitive measure of fear than directly observed freezing (at least as freezing was defined). Importantly, the fact that the degree of freezing and suppression are correlated supports the idea that conditioned suppression in rats does indeed reflect fear and therefore should be a good animal model for the study of fear acquisition and elimination in humans.

Frequently, rats will show strong suppression to novel CSs, particularly when they are brief. Looking only at suppression of the measured baseline responding, one might be tempted to believe that the novel CS is frightening. Direct observation, however, reveals otherwise (e.g., Ayres et al. 1987). Novel CSs tend to evoke a great deal of activity, including a lot of rearing (standing up on the hind legs). This behavior seems to reflect an orienting or investigatory response rather than a conditioned response. Thus, asking what the rat actually does during the CS can help to determine whether CS-evoked suppression does or does not depend upon CS-US pairings.

Cross-References

- ► Associative Learning
- ► Comparator Hypothesis and Learning
- ► Computational Models of Classical Conditioning
- ► Conditioned Inhibition
- ► Conditioning
- ► Context Conditioning
- ► Contingency in Learning
- ► Emotional Learning
- ► Fear Conditioning in Animals and Humans
- ► Pavlovian Conditioning

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Conditioned Taste Aversion

► Taste Aversion Learning

Conditioned Tolerance

► Drug Conditioning

Conditioning

► Associative Learning
► Learning in Honeybees: Associative Processes
► Psychology of Learning (Overview Article)

Conditioning Applications

► Behavior Modification, Behavior Therapy, Applied Behavior Analysis and Learning

Conditioning Therapies

► Behavior Modification, Behavior Therapy, Applied Behavior Analysis and Learning

Conditions of Learning

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Synonyms

Dispositions for learning

Definition

The conditions of learning, which were first postulated by Robert M. Gagné in the mid-1960s (Gagné 1965), and elaborated upon in many of his later works (e.g., Gagné 1985; Gagné and Medsker 1996), describe the specific events, both internal and external to the learner, Gagné postulated as supporting the various categories of learning outcomes that he identified in his work.

Theoretical Background

In order to understand the conditions of learning, one first must have an understanding of the five categories of learning outcomes that Gagné identified. These five categories are verbal information, intellectual skills, cognitive strategies, attitudes, and motor skills. Each of these five categories, along with the external instructional conditions that support learning within that category, is described below.

Verbal Information

Gagné (1985) indicates that verbal information involves the ability to *state, tell, or describe* facts, names, labels, and/or principles, either as individual entities or as interrelated elements, also known as bodies of knowledge (such as the names of all the capital cities in a particular region of the world). A person is said to have acquired, or learned, some verbal information when that person is able to state, tell, or describe that information in sentence form. Gagné points out that an essential characteristic of verbal information learning is that the learner states that information in essentially the same form in which it was presented, simply as a fact, name, label, and so on. In other words, the learner is said to have acquired that information simply by being able to restate it; the learner need *not* have to apply that information in order to demonstrate that he or she has learned it.

Conditions of Learning for Verbal Information

What are the conditions external to the learner that will facilitate the acquisition of verbal information? First, Gagné and Driscoll (1988) indicate that it is important to draw the learner's attention to the information to be learned. Oftentimes instruction entails a great deal of written and/or oral communication, only a small portion of which actually presents the verbal information that the learner is expected to recall. To help the learner identify and encode this information it is useful to employ verbal cues, such as the phrase "this is the key point to remember," or visual cues, such as a table, chart, or slide listing the key information.

Second, learners are more likely to remember information that is presented in small chunks. Presenting the to-be-learned information in short sentences facilitates encoding and recall. Limiting to four or five the number of items presented at one time is another useful chunking technique.

Third, it is important to provide the learner with a meaningful context that will help the learner encode that new information into the learner's existing cognitive structure. If names or labels are to be learned, placing that information into sentences or phrases is likely to help the learner remember that information. The rhyme that begins "Thirty days hath September . . . " is an example. Using visual imagery, having the learner create images that relate the new name or label with items that have already been learned, is another effective strategy. For example, a learner trying to learn that the Spanish word for a letter is "carta" is likely to be aided if the learner visualizes a letter being transported in a shopping cart (Pressley et al. 1982). Another effective strategy involves the use of advance organizers (Ausubel 1978), brief textual passages that precede the information to be learned and which attempt to link that information to the learner's preexisting knowledge.

Fourth, repetition is likely to improve learning and retention of verbal information. Learners may not encode some new information the first time they read or hear it, so repetition may be useful. Moreover, once a learner has encoded some information, providing the learner with spaced practice, requiring the learner to recall that information on multiple occasions over time, is likely to aid retention.

Intellectual Skills

Intellectual skills, also known as *procedural knowledge*, involve the ability to actually perform some intellectual task. Rather than simply being able to *state* some verbal information, the learner is able to *use* that information to perform a more complex intellectual task.

Gagné (1985) describes a variety of types of intellectual skills, including concrete concepts, defined concepts, rules, and higher-order rules. He indicates that concrete concepts are classes or groups of objects that can be identified by observation, in other words by examining their physical features, and which can then be classified by name. Examples would include types of columns, triangles, vehicles, and so on. Defined concepts are things or ideas that cannot be identified solely by their physical features, but rather by their definitions. For example, in order to classify someone as an uncle, a learner cannot simply look at a person's physical features. Instead, the learner must know that an uncle is defined as a person who is the brother of someone's mother or father, and determine whether the individual in question has that relationship.

Rules are statements that describe a procedure for solving a particular class of problems. Rule using involves the ability to apply that procedure in order to solve a class of problems. An example of a rule is "to add fractions with the same denominator, add the numerator and place the total over the common denominator." An individual who is able to add fractions by applying that rule is said to have learned the rule. Higher-order rule learning involves applying a combination of rules in order to solve a task that cannot be solved via the use of a single rule. For example, in order to write a business letter an individual must apply a wide variety of grammatical rules, including many rules involving grammar and sentence structure.

Conditions of Learning for Intellectual Skills

According to Gagné and Driscoll (1988), to increase the likelihood that a learner will be able to perform a particular intellectual skill, one must insure that the learner can perform the component skills that are subordinate to the skill being taught. For example, in most cases a learner must be able to identify independent clauses and coordinating conjunctions (concept learning) before the learner can correctly insert commas into sentences that contain those elements. Thus, before being taught the desired new skill, learners should be asked to recall the component skills, if they have already learned them, or should be taught those skills if they have not as yet acquired them.

In instances where the desired learning outcome involves concept learning, it is important that instruction direct a learner's attention to the distinctive features of the concept to be learned. Moreover, if learners are likely to have difficulty distinguishing between two closely related concepts, Gagné and Driscoll indicate that it is important to direct learner attention to the features that serve to differentiate the two. Thus, for example, if the goal is to teach learners to identify proper fractions, the instruction should not only include definitions and examples of proper fractions, but should also provide examples of fractions in which the numerator is larger than, or equal to, the denominator and an accompanying explanation as to why such fractions are not proper fractions.

Inasmuch as rule learning often involves performing a series of steps, Gagné and Driscoll indicate that one of the key instructional strategies for teaching such skills is to provide learners with cues that will help learners recall the sequence of steps, or a particular step, in the process. For example, a verbal cue that is likely to help a learner recall how to divide by fractions would be "invert the divisor and multiply." Obviously, in most cases stating this cue will just serve as one of many instructional events that will be employed as a learner is being taught the desired skill. Nonetheless, this cue is quite likely to be a crucial one, one that will help the learner recall the necessary procedure for dividing by fractions.

Gagné and Driscoll also suggest that rules that involve a large number of steps should be taught in chunks. That is, if a rule-using task involves more than one or two steps (e.g., balancing a checkbook), the learner might first be provided with instruction and practice on the one or two steps in the process before the learner is presented with instruction and practice on any of the other steps. It is important to point out that the employment of this approach, which has been labeled by some as a "part-task approach" (e.g., van Merrienboer 2007) does not preclude the possibility of beginning the instruction by demonstrating the entire process to learners so that they get a preview of the whole task.

Providing learners with opportunity to practice *applying* the rules they are being taught is another crucial condition of learning Gagné and Driscoll discuss. In doing so, they emphasize that simply because a learner can state a rule does not mean he or she can apply it; thus the need to have the learner practice application of the rule. Moreover, Gagné and Driscoll indicate that *spaced* practice, practice of the same rule on multiple occasions over an extended period of time, will greatly facilitate a learner's ability to retain the skill he or she has learned. Gagné and Driscoll also point to the value of having learners practice applying a skill in a variety of situations and contexts, thus promoting transfer of that skill.

Finally, Gagné and Driscoll point to the importance of feedback during rule using. They discuss the value of reinforcing correct responses and point to the importance of corrective feedback when learners are having difficulty performing a rule-using task properly.

Cognitive Strategies

According to Gagné, cognitive strategies are the means via which learners guide their own remembering, thinking, and learning. For example, a learner might use a mnemonic device in order to recall the names of the planets in our solar system.

Conditions of Learning for Cognitive Strategies

Cognitive strategies are often developed by learners independently as they engage in some learning activity. Nonetheless, Gagné and Driscoll (1988) indicate that there are at least three categories of instructional activities that can be employed in order to help learners acquire and use cognitive strategies. First, cognitive strategies may be demonstrated and/or described to the learners. For example, when learners are being taught how to solve complex problems, a strategy for identifying the essential and irrelevant ideas presented in the problem situation can be described and demonstrated to the learners. As additional problems of this nature are presented, demonstrations of how to apply the strategy may be faded and replaced by simple instructions reminding the learners to apply the strategy.

Second, Gagné and Driscoll discuss the importance of providing learners with frequent opportunities to practice employing cognitive strategies. They suggest that providing students with a variety of novel problems within a particular content area will facilitate their ability to apply a particular cognitive strategy or set of strategies to other novel problems within the same area. Third, Gagné and Driscoll point to value of providing learners with informative feedback as they are learning cognitive strategies. They indicate that this type of feedback does not simply inform the learner as to whether his or her proposed solution to the problem was correct; in addition it might indicate the extent to which the process the learner employed in arriving at the solution was original, creative, or inventive (this assumes that the strategies that were employed are observable). In addition, one might presume that such feedback could also focus on the efficiency of the strategies the learner used. Moreover, in those cases in which strategies did not meet particular criteria, it would be useful to provide feedback recommending alternative techniques.

Motor Skills

Gagné indicates that motor skills usually involve a sequence of physical movements that "constitute a total action that is smooth, regular, and precisely timed" (Gagné 1985, p. 62). Examples include a wide array of physical activities, such as serving a tennis ball, driving a car, printing the letters of the alphabet, performing a type of dance, and innumerable other physical actions.

Conditions of Learning for Motor Skills

According to Gagné and Driscoll (1988), one of the important steps in teaching learners how to perform a particular motor skill is to describe and demonstrate the various physical procedures (also called the *executive subroutines*) which constitute that skill. They also suggest that for complex skills, in addition to demonstrating the skill as a whole, it is valuable to divide the skill into parts and describe and demonstrate each part separately.

The authors also point to the importance of providing learners with many opportunities to engage in the physical practice of a motor skill so that learners can not only learn how to perform the skill, but can have opportunities to fine-tune that performance. Moreover, Gagné and Driscoll indicate that in some cases it may be valuable to have learners engage in mental practice of physical skills, indicating that learners may benefit from forming mental images of how to perform the skill.

As Gagné and Driscoll indicate, when learners are engaged in the physical practice of a motor skill, it is also very important to provide learners with feedback regarding their performance. The authors pay particular attention to two characteristics of the feedback that should be provided to learners when they are engaging in physical practice of motor skills. First, they discuss the importance of immediate feedback, indicating that if feedback is not immediate, learners may get into the habit of performing a skill incorrectly, making it that much harder to teach them the proper execution of the skill. Second, they discuss the need to provide informative feedback, namely feedback that indicates to the learner what aspect of performance was faulty and describing or demonstrating the correct manner of performing that action.

Attitudes

Attitudes, according to Gagné (1985), are the internal feelings or beliefs that influence the choice of personal actions an individual takes. For example, a person's beliefs about the value of wearing a seat belt while driving is likely to influence his or her decision as to whether to use one.

Conditions of Learning for Attitudes

Gagné and Driscoll (1988) describe a variety of learning conditions that can be employed to promote learner acquisition of particular attitudes. One involves the use of human modeling. They suggest that learners may be influenced to adopt a particular attitude if they are shown examples of a positive role model, someone they admire or respect, displaying that attitude. The authors point out that usually it is not sufficient to simply have the model talk about the value of adopting a particular attitude, it is important that the model actually display the action that reflects that attitude. For example, rather than simply stating it is important that drivers bring their cars to a complete stop at stop signs, a model should also display that behavior.

Another strategy involves establishing an expectancy for success on the part of the learner. Gagné and Driscoll indicate that if learners are rewarded or experience some form of success after engaging in some action based on personal choice, they are more likely to continue to engage in such actions. In other words, the learners will be more likely to adopt the attitude that led to that choice of action. For example, an individual who receives praise for recycling an item is more likely to continue to engage in recycling. In a similar vein, Gagné and Driscoll indicate that when a role model engages in some attitudinal behavior, it is important to demonstrate how the role model is rewarded or receives some satisfaction from taking that action. For example, a role model might discuss the satisfaction he or she received from doing some voluntary service activity (such as the satisfaction I have received from preparing this entry for this encyclopedia!).

Important Scientific Research and Open Questions

Many of the studies that have examined Gagné's views regarding the conditions of learning have focused on a particular instructional event or condition that he postulated as facilitating a particular type of learning outcome. For example, as noted earlier, Gagné (1985) indicated that intellectual skills that involve a large number of steps should be taught in small chunks, with the learner receiving instruction and practice on a few steps at a time. In recent years, several authors (e.g., van Merrienboer 2007; Merrill 2009) have raised questions about this viewpoint. As a result, several researchers have compared instructional approaches that employ this "part-task approach" with a "whole-task approach" in which, from the outset of a lesson, the practice activities presented to learners require them to perform all the skills or steps that constitute the whole task, starting with a simple version of the whole task and, over time, progressing to more complex versions of the task. Results of a recent study revealed that skill acquisition and transfer was greater among students in a whole-task condition than among students in a part-task group (Lim et al. 2009). However, the researchers clearly indicated that a great deal of additional research is necessary in order to get a clearer picture of the relative merits of these two approaches across a wide variety of cognitive skills and learners.

Research has also been conducted on many of the other instructional conditions or events of instruction described by Gagné. In a few instances, research has centered around Gagné's views regarding a particular event, such as providing learning guidance (Alutu 2006) or presenting instructional cues (Tomic 1980). In a much larger number of cases, researchers have examined how various levels of a particular instructional event, such as modeling behaviors (West and Graham 2007) or providing feedback (Ifenthaler 2011), affect learning. However, most of these studies have not specifically focused on Gagné's views regarding these events.

While some studies related to Gagné's work have focused on a single instructional event or condition, several studies have focused on lessons or materials that incorporate several of the events of instruction described by Gagné and have examined how the presence versus absence of one or more of these events affected student learning and attitudes. In several such studies (Martin et al. 2007; Martin and Klein 2008), providing learners the opportunity to practice desired skills proved to be the instructional event that had the greatest effect on learning. These studies call for further examination of how a combination of Gagné's events of instruction affect student learning and attitudes.

Other studies have focused on the degree to which Gagné's events of instruction are employed during a lesson, and have examined how various levels of use are correlated with student learning and attitudes. For example, in a study examining the instructional activities employed in 37 sections of undergraduate computer science and chemistry courses, Hampton and Reiser (2004) found that student learning and motivation were positively correlated with the degree to which Gagné's events of instruction were employed.

Many models of teaching that are often characterized as "direct instruction" (Magliaro et al. 2005) prescribe the use of a set of instructional activities similar to Gagné's events of instruction. Given the current debate about the appropriate degree of instructional guidance that should be provided to learners (Clark and Hannafin 2012), there is a need for additional research examining the effects of direct instructional approaches such as those proposed by Gagné.

Cross-References

► Abilities to Learn: Cognitive Abilities
► Attitudes: Formation and Change
► Chunking Mechanisms and Learning

► Cognitive Skill Acquisition
► Feedback Strategies
► Learning by Chunking
► Learning Strategies
► Meaningful Verbal Learning
► Mnemotechnics and Learning
► Motor Learning
► Rule Formation

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Cone of Experience

► Multimodal Learning Through Media

Cone of Learning

► Multimodal Learning Through Media

Confidence in Retrieval

► Calibration

Confidence Judgments in Learning

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Synonyms

Metacognitive judgments

Definition

In research about ► metacognition (for an overview see Dunlosky and Metcalfe 2009) confidence judgments or metacognitive judgments are defined as assessments of the current state of knowledge. Thus, referring to

► cognitive learning students assess their own knowledge themselves at certain points of time during their learning. In this regard three kinds of judgments are of particular interest: *ease of learning* (EOL) judgments that are taken before the learning begins, *judgments of learning* (JOL) that are taken after learning but before a performance test, and *retrospective confidence* (RC) judgments that are taken after testing.

Theoretical Background

In the framework of metacognition proposed by Nelson and Narens (1992), cognitions are split into two levels, namely, the object-level and the meta-level. All cognitions about the content to be learned are located at the *object-level*, for example, activities like reading or elaborating, and representations like the definitions of terms or mental images of pictures. Mental representations about these cognitions are located at the *meta-level*, for example, the belief that a certain learning strategy will be efficient, the plan to reach a learning goal, the belief that one has comprehended the content, etc. Thus, the learner constructs a mental model at the meta-level that maps the cognitions at the object-level, and this model may be altered as the learning process continues, that is, the model at the meta-level changes. One of the processes that potentially alter the mental model is *monitoring* that is defined as assessing the cognitions at the object-level. Confidence judgments are an important part of this monitoring as they assess the current state of knowledge about the learning content. After the knowledge has been judged and the mental model has been updated, the cognitions on the object-level may be controlled. Thus, besides monitoring *control* is the second important process in the framework by Nelson and Narens (1992). During learning such control may lead to rereading, selection of another study-strategy, etc.

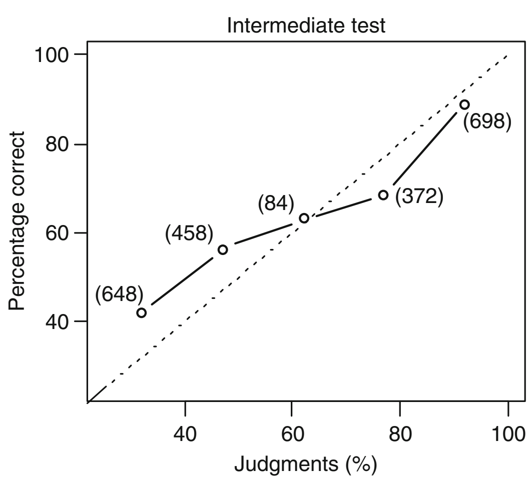
We will elaborate on the role of judgments in learning more deeply using an example. Assume that Jennifer reads a text about the functioning of a steam engine as a part of her preparation for an exam. Before she begins to read she asks herself how difficult it will be to comprehend this text, that is, she judges her EOL. Depending on her judgment she will reserve time for reading about steam engines and allocate less or more study-time to other themes. Afterward she begins reading, but she decides not to read some of the additional material that is printed in boxes throughout the main text. Then she judges how well she has understood the text and how good she will be at the examination, that is, she judges her learning (JOL). As she feels that she has not got everything right, she decides to reread some parts of the text and to have a look at the boxes that she neglected during her first reading. Coming to the end of the text again, Jennifer fills in the practice test at the end of the chapter. Because she feels very confident that her answers in the practice test are correct (RC judgments) she decides not to read anymore about steam engines. From an educational perspective the core question is: How well will Jennifer do at her examination? The answer to this question partly depends on the accuracy of her judgments, because her decisions during learning are conductively only if the judgments reflect the actual knowledge at that point of time in the learning process. Otherwise she will allocate study-time toward texts that she already knows, reread text parts superfluously, and she will not invest additional effort for learning following an illusion of knowing. Thus, confidence judgments are a central component of ► self-regulated learning and affect the learning process and the learning outcome. But how are judgments and their accuracy obtained? We will give a brief introduction into the methods in the next section.

To obtain confidence judgments learners are usually asked questions like "How well will you be able to complete a test over this material?" The answer is often given using a scale from 0% to 100%. If a multiple choice test is used the lower limit is adjusted to guessing, for example, 20% for an answer format using five alternatives. As the actual parameter for guessing can differ from this value depending on the used distracters – see 3-PL models in item response theory – we suggest using open answer formats or other formats with a guessing nearby 0% whenever possible. Judgments can be obtained as local or global judgments. *Local* EOL judgments or JOLs are obtained for each content or text section to be learned; local RC judgments are obtained after each item of a test. In contrast *global* judgments are made for the whole learning material or the whole test. As we have argued above, the accuracy of judgments is crucial for self-regulated learning and for learning outcome. There are mainly two different kinds of accuracy measures calculated: *Absolute accuracy* (aka calibration) is based on the difference or the absolute difference between the judgment and the performance indicating how much learners' judgments derivate from their performance. Absolute accuracy can be visualized plotting calibration curves (see, e.g., Fig. 1) that are indicating under- and ► overconfidence at each level of confidence. A prerequisite for calculating absolute accuracy is that judgments either are made on the same scale as the performances (e.g., "I will solve 12 items correctly") or on a percentage scale. *Relative accuracy* (aka resolution) indicates to what extend learners discriminate between test performances on correct vs. incorrect items. Relative accuracy is calculated as the within-person correlation between the judgments and performances, often using the nonparametric gamma correlation. A prerequisite for calculating relative accuracy is that local judgments have been used.

Important Scientific Research and Open Questions

In this section we will briefly review core research about confidence judgments in learning and stress major research questions. Four topics are addressed: (1) judgments, study-time allocation, and learning outcome; (2) enhancing JOLs' accuracy; (3) stability and generality of judgments and their accuracy; and (4) calibration in classroom studies.

Researchers have been interested in study-time allocation as a part of metacognitive control during learning (see, e.g., Dunlosky and Metcalfe 2009). Study-time allocation was mainly studied in laboratories using word pairs or short sentences as learning material. One result is that JOLs predict the allocation of study-time in a following learning phase. There are two hypotheses explaining this result. The *discrepancy-reduction hypothesis* states that study-time is allocated to those items that are judged as least known, whereas the *region-of-proximal-learning hypothesis* states that study-time is allocated to those items that are judged as not yet known, but among these items the easiest ones will be chosen first. There is evidence for both hypotheses found in the literature, and maybe both mechanisms are used by learners. However, each of the hypotheses explains why the accuracy of judgments is related via the mediator study-time allocation to the learning outcome. And indeed, there is evidence for JOLs' relative accuracy being correlated to the learning outcome in text comprehension (Maki and McGuire 2002). Beyond that experiments have shown that enhancing JOLs' accuracy causes an increase in learning outcome. Moreover researchers have shown that the relative accuracy of RC judgments is correlated with comprehension in reading too. In sum this body of research supports the claim that JOLs and RC judgments are important for the control of learning processes, and that self-regulation is effective only if the accuracy of these judgments differs from zero.



Confidence Judgments in Learning. Fig. 1 Example of a calibration curve using RC judgments. Frequencies of judgments are given in *brackets*. The *dotted line* indicates perfect calibration. Cited from Mengelkamp and Bannert (2010)

Based on the function of confidence judgments for learning there has been considerable effort made to enhance the accuracy of judgments (see, e.g., Dunlosky and Metcalfe 2009; Dunlosky and Lipko 2007). There are several interventions found to be effective in pushing the relative accuracy of JOLs: (a) JOLs are more accurate if they are obtained delayed rather than immediately after learning. One explanation is that delayed judgments include processes of activation from ► long-term memory only whereas immediate judgments additionally rely on ► working memory. In contrast performance in a knowledge test is based on long-term memory and therefore the delayed judgments reflect the knowledge more accurately than immediate judgments. (b) Deeper understanding of texts facilitates the relative accuracy of judgments, for example, throughout rereading, writing summaries, and generating key terms before taking the JOLs. But how is this effect explained? Firstly, it is known from the ► levels of processing approach that deep processing leads to better comprehension of texts. Secondly, techniques like generating key terms are indicative for the depth of processing. As JOLs reflect the depth of processing and the performance reflect the depth, too, the relative accuracy of the judgments increases.

From an interindividual perspective, the stability and generality of judgments and their accuracy was investigated (see, e.g., Mengelkamp and Bannert 2010). There is evidence that the judgments themselves are considerably stable over the time at least within each kind of judgment, and this corresponds to evidence from research using RC judgments in test-taking. This stability may reflect stable characteristics of persons like beliefs about one's own ability or self-confidence. Further, it was questioned if there is a stable and general metacognitive ability; thus the stability and generality of the judgments' accuracy is of interest. Results indicate that relative accuracy is not stable at all and generalizes not across different domains. In contrast absolute accuracy seems to be moderately stable and generalizable. But as absolute accuracy is not mathematically independent from the magnitude of judgments and the magnitude of performances, the latter result potentially is an artifact. To sum up this section, relative accuracy of judgments seems not to be much of a trait but it is sensitive to characteristics of the learning situation and thus open for interventions.

The research presented so far was mainly conducted in laboratories using relative measures of accuracy. Since the late 1990s, there is a growing body of research that has been conducted in classrooms using absolute measures of accuracy (see, e.g., Hacker et al. 2008). One result is the replication of the "unskilled but unaware" effect in educational settings, that is, low-achieving persons overestimate themselves whereas high-achieving persons are quite well calibrated or show slight underconfidence. Further, almost all studies found a correlation between the absolute accuracy of JOLs or RC judgments and the final test performance. Therefore, one aim of research in the classroom is to get students better calibrated in order to improve the learning outcome. There are some studies addressing this aim using RC judgments. One obvious way is to give practice tests toward the students in order to increase their accuracy of judgments. First results show that giving the students practice tests together with judgments and feedback is not increasing the absolute accuracy of their judgments. But if monitoring was trained explicitly and incentives for accurate judgments were given, a positive effect on calibration and performance in the final test was achieved.

Confidence judgments are important for learning. Nevertheless it is often ignored that judging ones knowledge during learning is a highly complex process, and in order to improve learning significantly theories of SRL and metacognition need to be integrated.

Cross-References

- ► Comprehension Monitoring
- ► Metacognition and Learning
- ► Metacognitive Strategies
- ► Self-regulated Learning

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Configural Cues in Associative Learning

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Synonyms

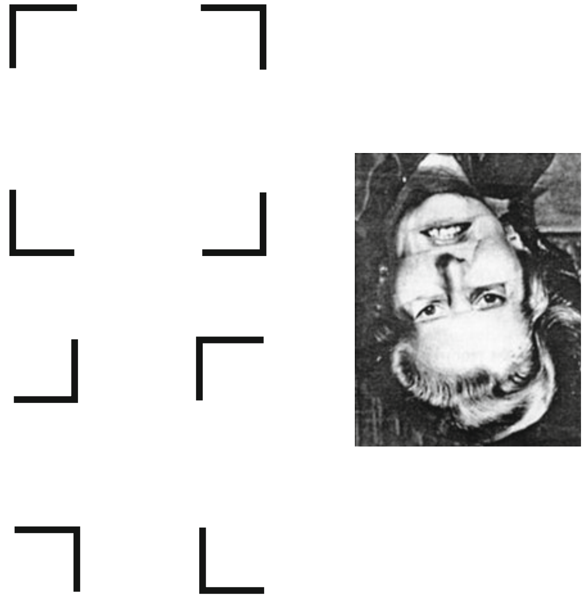
Conjunction; Part; Pattern; Stimulus configuration; Whole

Definition

Configural cues are stimuli provided by the juxtaposition, in time or space, of individual stimulus elements. Associative learning is said to have taken place when presentation of a stimulus elicits a new response as a result of a history of pairing with another stimulus. The outcomes of many associative learning experiments demonstrate that organisms use configural cues during learning.

Theoretical Background

As long ago as 350 BC, Aristotle considered the distinction between individual elements and their assembly: “In the case of all things which have several parts and in which the totality is not, as it were, a mere heap, but the whole is something beside the parts . . .” (Aristotle, 350 BC, Book VIII, Part 6; as cited by Ross (2009)). More recently the Gestalt psychologists are commonly associated with the expression “the whole is greater than the sum of its parts” for which Aristotle’s words are one precursor. The general principle referred to is straightforward and there are many nice visual examples from the perception literature, such as the one shown on the left of Fig. 1. The arrangement of four corners in the top left gives the impression of a square shape, which is quite different to the impression formed when the same elements are rearranged, as shown in the bottom left of the figure. Discussions of stimulus configuration effects are not confined to the perception literature. Other examples arise in different areas of psychology including attention, face perception, and associative learning. In studies of divided attention it has been argued that response times when two signals (e.g., tone and letter) are presented together are faster than could be expected if the signals are processed separately on independent channels. Instead, it has been suggested that attention is allocated to a third signal internally generated from the combination of the two experimenter defined signals. The Thatcher illusion has been proposed as evidence in support of the view that configurations of facial features play an important part in face perception. The face of Margaret Thatcher, shown on the right of Fig. 1, does not appear dramatically unusual at first glance. However, when viewed after a rotation of 180° the corruption of the image is readily apparent. Upright viewing uses configural cues coding the relationships between features and thus facilitates rapid identification of anomalies such as feature inversion.



Configural Cues in Associative Learning. Fig. 1 Stimuli exhibiting “configuration” effects. Left-hand-side two arrangements of four corners, and right-hand-side, the Thatcher Illusion

Early demonstrations of configural effects in associative learning appeared in the western literature during the 1930s. Following-up on the work of other Russian investigators, including Pavlov, Gregory Razran documented faster learning in humans when compound stimuli were used as conditioned stimuli than when individual elements were used. Salivation responses were acquired more rapidly to an alternating pattern of red and green lights which signaled food than to a single red or green light of the same duration. A little later, Charles Woodbury was working with dogs and found that the dogs could learn a negative patterning discrimination. This discrimination involves reinforced presentations of two stimuli presented individually but non-reinforcement of the two stimuli presented in compound, a procedure which can be summarized as a series of intermixed A+, B+, and AB− trials. The fact that conditioned responding can be lower to a compound than to either of the elements presented alone shows that the animals were responding to something that was unique to the compound, distinguishing it from the elements from which it was composed. Other discriminations, such as a biconditional discrimination (AB+, BC−, CD+, and AD− trials), which can be readily solved by humans and animals, also suggest that stimulus configurations are attended to during associative learning. In the biconditional discrimination, all stimulus elements are reinforced and non-reinforced equally often; therefore, alone, they cannot inform the subject of the response requirement. Instead, to respond appropriately in this type of task it is necessary to processes stimulus conjunctions such as "A and B."

Of course, because these configural cues are unobservable theoretical entities, inferred as a means to understand behavior in particular experimental situations, there has been considerable speculation about their underlying nature. It is commonly thought that configural cues are processed in the same way as elemental cues and, following Clark Hull's lead, that they arise as the result of a perceptual interaction between simultaneously or successively presented stimuli. So, it is supposed, for example, that a tone sounds slightly different when presented in compound or soon after a buzzer (and the sound of the buzzer is changed in a similar way) and the "unique elements" generated by the compound code the conjunction. Hull coined the phrase "afferent neural interaction" to capture this idea. However, one challenge to this notion has arisen from the suggestion that the unit of analysis should be the pattern itself, rather than the elements. Pearce (1994) argued that all of the elements present in a stimulus are represented as a single configural unit, or pattern, and it is this pattern which is processed by the learning mechanism. Thus, during biconditional discrimination four different patterns (AB, BC, CD, and AD) gain associative strength. Although reinforcement is distributed evenly across the elements (A, B, C, and D) rendering a simple elemental account of learning of this discrimination inadequate, there is differential reinforcement at the level of pattern. The fact that the patterns in a biconditional discrimination share some elements, and hence have nonzero similarities, means that this discrimination should be more difficult to learn than one which just involves A+, B−, C+, and D− trials. The fact that biconditional discrimination is learned more slowly than a simple discrimination is consistent with this analysis.

Important Scientific Research and Open Questions

Although it is clear that humans and animals can represent and learn about stimulus configurations the best characterization of those representations is not firmly established. Wagner recently proposed an elaborated version of the configural cue hypothesis, the Replaced Elements Model. In the Replaced Elements Model stimulus compounds not only generate new configural cues but also, simultaneously, these configural cues inhibit components of the original elements. So, a compound of A and B generates a representation of the conjunction, c, and at the same time produces some changes in A and B so the final characterization of the compound is $A'B'c$ (see Wagner 2008). One of the advantages of such a model is that it naturally predicts asymmetrical generalization gradients from adding and removing elements. According to this model, after conditioning of A, if a test trial of an AB compound is presented then the loss of responding will be proportional to the difference between A and A' (the novel B' and c components of the compound are not assumed to affect responding). On the other hand, after conditioning of an AB compound, should a test trial of A be presented then the loss of responding will be proportional to the difference between $A'B'c$ and A. In most situations it would be expected that the difference between $A'B'c$ and A would be greater than the difference between A and A'. Studies with humans and animals have confirmed this result (Brandon et al. 2000; Glautier 2004). Moreover, this "Replaced Elements Model" is significant in that it allows for a degree of flexibility in the extent to which cue conjunctions are encoded. This idea is consistent with a developing view in the literature that different experimental preparations can result in a more or less configural representation of the stimulus compounds which are presented (Melchers et al. 2008).

Cross-References

- ► Associative Learning
- ► Computational Models of Classical Conditioning
- ► Conditioning
- ► Discrimination Learning
- ► Formal Learning Theory
- ► Representation Changes in Learning

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Confirmation Bias

The tendency to search and select information confirming personal hypotheses and beliefs, ignoring contrary evidence.

Conformist Bias

► Theory of Conformist Social Learning

Conformist Transmission

► Theory of Conformist Social Learning

Conformity

► Reproductive Learning

Confucian Educational Philosophy

► Confucian Educational Philosophy and Its Implication for Lifelong Learning

Confucian Educational Philosophy and Its Implication for Lifelong Learning

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Synonyms

Confucian educational philosophy; Confucianism; Confucius; Lifelong education; Lifelong learning

Definitions

Confucius (551 B.C.E. – 479 B.C.E.) was the greatest educator, philosopher, and eminent figure in the history of China. Confucius is a latinized name for "Kong Fu Zi" by the Italian Jesuit Matteo Ricci (1552 C.E. – 1610 C.E.), when Confucian works started to be introduced to the Western world during the late sixteenth century. His last name was Kong, people generally called him "Kong Fu Zi." "Fu Zi" added following a surname was an honorific title back then, which meant Master. "Kong Fu Zi," translated as Confucius, thus has been known to the world.

Confucianism started from the thoughts of Confucius (Huang 2006; Zhang 2009), developed, enriched, and joined by the thoughts of Mencius (372 B.C.E. – 289 B.C.E.), Xun Zi (298 B.C.E. – 238 B.C.E.), and other followers. Historically, Confucianism has gone through many stages, such as the "original Confucianism," the "Han Confucianism (206 B.C.E. – 220 C.E.)," and the "Neo-Confucianism." For over 2,500 years, Confucian philosophy has exerted a profound influence on almost every aspect of Chinese society, particularly, in the education arena.

Lifelong learning is a broad concept. It generally denotes that learning, either for personal, professional, institutional/organizational, and/or societal purposes, continues via all kinds of learning activities throughout life span, whether formal, nonformal, and/or informal. Lifelong learning has been interchangeably utilized with concepts such as *lifelong education, continuing education, continuing professional education, recurrent education, adult learning, and adult education.*

Theoretical Background

Although both Eastern and Western cultures can trace their origins and the use of the concept in historical documents, A. B. Yeaxlee, a British educator, first addressed the need for lifelong education in the UK at the beginning of the twentieth century (Holford and Jarvis 2000; Wain 2004). Then, two noteworthy publications have made the concepts of lifelong learning and lifelong education become consciously discussed and internationally accepted. *Learning to Be* (1972), Faure's report for the United Nations Educational, Scientific and Cultural Organization (UNESCO), became the benchmark of advocating lifelong learning opportunities for everyone, independent of class, race, or financial means, and independent of the age of the learner. Paul Lengrand's book, *An Introduction to Lifelong Education* (1975) made the concept of lifelong education become widely spread. More importantly, many nations and policy makers have considered and applied lifelong learning as a strategic plan for national development.

UNESCO, Organization for Economic and Co-Operation and Development (OECD), the Council of Europe (CU), European Union (EU), and World Bank have been the major players in publicizing and developing these concepts among their member countries since the 1970s. They have also made policies that turned the concepts into strategies and practices significantly during the past decades.

Since the 1970s, the development of lifelong learning and lifelong education has gone through different stages characterized by different goals and purposes under certain philosophical orientations. Schuetze (2006), in his analysis of the work and documents of UNESCO, OECD, the World Bank, and EU, depicted that the first stage began in the 1970s and ended in the late1980s, during which time lifelong learning was humanistic and democratic oriented. It aimed to provide learning opportunities for everyone without distinctions of class, race, gender, age and financial means. The second stage started in the 1990s and married economic rationale with wider societal objectives, becoming a convenient umbrella term for an evolving "new educational order" to fill the social demand for education and for learning opportunities outside the formal system, which illustrated pragmatism in nature. Schuetze described that the goal of lifelong learning in this phase, as seen by many European countries, "as an instrument for social mobility, equality of life chances, social cohesion, and active citizenship, ensuring that all, young and old acquire and maintain the skills, know-how and dispositions needed to adapt to changing jobs and labor markets" (2006, p. 292).

Other scholars (e.g. Wain 2004) pointed out that the first phase followed the Faure report in 1972, which was philosophically utopian, aiming at holistic education that respects the unity and complexity of the person. Wain used Lengrand's statement that caters to "every aspect and dimension of the individual as a physical, intellectual, emotional, sexual, social and spiritual beings" (1975, p. 96) and corresponds with the activity of multiplying the dimensions of human existence rather than shrinking them to one kind, the intellectual. The second phase, started in late 1970s, which looked for concrete practices of lifelong education, was a pragmatic approach, reacting to the criticism of the utopian approach, and focusing on present issues rather than future visionary possibilities.

Still others (e.g. Dehmel 2006) believe there are three phases in the development of the concept. Dehmel described that the first phase was from the early 1970s to mid-1970s. The second phase began in the early 1990s. Between the two phases was a valley of decreasing. He argued that the first phase was strongly influenced by humanistic ideals, calling for education for all throughout their lives toward extensive social and cultural aspects and via various kinds of educational systems. During the "valley" time, the interest decreased due to the economic crisis at the time, when international and intergovernmental interests shifted. Starting in the1990s, the fast movement of globalization, new information technology, and an aging society were just a few facets that influenced the shift toward utilitarian and economic objectives.

In Europe, the concept has recently kept on changing due to criticisms of the narrow scope that focuses on work skills formation, labor markets perspectives, and a knowledge-based economy or society (Schuetze 2006). UNESCO, OECD, and EU have combined social and cultural goals with the economic rationale since late 1990s (Dehmel 2006; Green 2006). One example would be *Learning for all* published by OECD in 1996, which says, "We are all convinced of the crucial importance of learning throughout life for enriching personal lives, fostering economic growth and maintaining social cohesion" (OECD 1996, p. 21).

Today, the emergence of the knowledge economy in an era of globalization evidently leads to an increasing economic competitiveness, thus makes lifelong learning primarily a governmental instrument for the promotion of a knowledge society, skills' formation, transferable skills, multiskilling and careership, which all reflect human capital theory (Green 2006; Olssen 2006).

As can be seen, from a humanistic tradition, the concept understands individual growth and development. Embedded in the pragmatism, it sees the need for societal and organizational improvement, for social development or transformation. Then, influenced by the utilitarianism and human capital theory, it centers on economic effectiveness as opposed to a social political perspective advocating citizenship.

We would all agree that each argument embraces valid points. However, from the Confucian perspective, all seems to exclude other equally important dimensions of human development via lifelong learning. It is in this context that the Confucian educational philosophy presents us significant implication for lifelong learning and lifelong education.

The core of Confucian educational philosophy is how we learn to be human. Human beings are the ends not the means. Confucius believed that the ultimate end of learning was to realize the true nature of human beings – become fully human. We are all human beings. However, we are not born fully human. Each of us must still consciously learn to be so. To Confucius, lifelong learning enables human beings to realize and practice their true nature and live happily in and with the worlds of different kinds: universe, nature, society/other human beings, and inner self (Sun 2004). Thus, the Confucian educational philosophy has a fuller perspective on purposes and functions of lifelong learning. Several conceptions *Ren, Sage, and Jun Zi* reviewed by Sun (2004, 2008) are critical in understanding the Confucian multidimensional learning.

Ren: Generally translated as humanity, morality, and righteousness, it is the backbone of Confucian philosophy, which has manifestly influenced Confucian educational thought and practice. From an axiological perspective, *Ren* is the utmost virtue of the Universe. It is the totality of morals. It leads human beings to manifest their true nature. Confucius understood that humans are potentially moral. Yet, the potentials need to be cultivated and developed through lifelong learning and practice. From an epistemological perspective, *Ren* is the knowledge of morality and humanity. Confucius believed *Ren* is gained through lifelong self-cultivation. In fact, the processes of lifelong learning deepen the facets of developing morality and humanity toward a multidimensional world of which humans are a part.

Sage: It is the Confucian ideal human model, who has realized *Ren*. "*Sage* is one who has reached the highest realm and become (1) the undivided "I" with the Universe; (2) the unity of "I" with other humans and other beings; and (3) the wholeness of "I" with self" (Sun 2004, p. 79). With this nature, sage, being at the most perfect stage, can fully develop his or her own nature. More importantly, he or she can fully develop the nature of his or her fellows and all other things. In fact, he or she is able to assist the transforming and nourishing powers of Heaven and Earth, and ultimately form a triad with the Universe. Confucius positively advocated that through lifelong learning and practice every human being was capable of gaining access to *Ren*, to be a *Sage*. This ideal human model framed the realistic purpose of the Confucian learning, which is to educate *Jun Zi*.

Jun Zi: A term Confucius adopted and replenished the meaning to refer to a person who is willing to learn and practice *Ren* via lifelong learning and cultivation. *Jun Zi* also stands for the Confucian educated, an exemplary and model characterized by outstanding knowledge, courage, and multiple skills. Ideally, *Jun Zi* learns to realize and manifest his or her true nature toward the universe, the natural world and other beings, the social world and other humans, and the inner world of self. Toward the universe, *Jun Zi* respects the Tao of Heaven and understands each human's fate (Lun Yu, [the Analects], XVI, 8; XX, 3). Toward society, *Jun Zi* has strong social accountability. Toward other beings, *Jun Zi* follows the precept "do not impose on others what you do not desire (Lun Yu, XII, 2; XV. 24)." Toward self, *Jun Zi* never ceases self-strengthening.

Jun Zi holistically develops the wholeness and becomes a multidimensional model of learning and doing, to be harmonious in both internal and external qualities. In the social sphere, for instance, he or she not only cultivates the self but also establishes others. He or she is not only a self-directed learner but also an educator of others. He or she is not only knowledgeable but also action oriented.

Hence, the Confucian educational philosophy presents significant implications for the practice of today's lifelong learning. Comparing with the Western approaches to lifelong learning, Confucian educational philosophy through the ideal human model of *Sage* and realistic educational end *Jun Zi*, presents holistic and multidimensional goals and functions for human beings to learn lifelong. As can be seen, the Confucian lifelong learning includes but also goes beyond the purposes advocated by each stage of the development of lifelong learning during past several decades, whether humanistic for personal development, or pragmatic and utilitarian for economic crisis. For Confucius, human beings live in and interact with different worlds: universe, nature, society, and self. Thus, human beings need to learn for and from, live with, and live in each reality. All help realize the true and complete nature of being human. In other words, any single aspect of development no matter how successful and full will only lead to an incomplete of a human being.

Important Scientific Research and Open Questions

Since 1970s, the functions and goals of lifelong learning have been changed from one set to another to practically meet needs under new contexts. These modifications also reflect efforts of scholars' debates and criticism on the narrowly focused purposes associated with certain philosophical beliefs (Dehmel 2006; Holford and Jarvid 2000; Schuetze 2006). Researchers have called for an overarching conceptual framework, "one that describes the basic dimensions, relates central elements and points to strategic issues and considerations relevant for policy and practice" (Tuijnman and Boström 2002: 105). In a changing society, lifelong learning must be on the condition of human beings (Lindgren 2002). However, we are experiencing, "the key driver of the development of lifelong learning is thus the emergence of the knowledge economy in an era of globalization" (Hinchliffe 2006, p. 94). Evidently, the current practice of lifelong learning leaves some of the other dimensions of human existence out that they have vanished from sight. What do we miss? Should we revisit the centuries' old question: What is the purpose of learning and education? Are human beings the ends or the means of lifelong learning? Do we now have different understandings of ends and means than did ancient sages such as Confucius? What can we learn from the Eastern ancient educational philosophy for the modern practice of lifelong learning? More importantly, could lifelong learning resolve all kinds of social ills and economic problems, without looking at the center that is our human beings? These fundamental yet overlooked questions invite us to critically ponder and move beyond our own paradigms of thoughts.

Although Western thought and way of thinking have become dominated through its "scientific" research, more and more scholars (Merriam and Associates 2007) acknowledge that there are truly huge missing parts of non-Western outlooks that could benefit the whole human beings' learning. Optimistically, Confucian philosophy and his educational practice may provide us alternative lens and perspectives to find possible solutions if we are willing to explore and open to perspectives other than our own (Sun 2008).

Cross-References

- ► Experiencing Wisdom Across the Lifespan
- ► Learning and Fluid Intelligence Across the Lifespan
- ► Lifelong and Worklife Learning
- ► Mental Models and Life-Long Learning
- ► Values in Education and Life-Long Learning

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Confucianism

► Confucian Educational Philosophy and Its Implication for Lifelong Learning

Confucius

► Confucian Educational Philosophy and Its Implication for Lifelong Learning

Confusion's Impact on Learning

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Synonyms

Uncertainty

Definition

Confusion is a cognitive-affective state that occurs when a person is aware of an inconsistency between their knowledge and observed information and is actively seeking to reconcile the discrepancy.

Theoretical Background

Recent empirical research has pointed to confusion as an important affective state for scientific study (Rozin and Cohen 2003). Confusion indicates an uncertainty about what to do next or how to act (Graesser et al. 2007). Thus, confusion accompanies cognitive disequilibrium which plays an important role in comprehension and learning processes (Piaget 1952; Graesser and Olde 2003).

Under this theory, people start in a state of equilibrium. In this phase, they are processing information from the world around them, but not always at a deep level. Deep comprehension occurs when learners confront contradictions, anomalous events, obstacles to goals, salient contrasts, perturbations, surprises, equivalent alternatives, and other stimuli or experiences that fail to match expectations (Mandler 1976; Schank 1986). At this point, the person moves into a state of cognitive disequilibrium where a misunderstanding is realized and attempts are started to reconcile the conflicting internal and external sources of information. Cognitive disequilibrium has a high likelihood of activating conscious, effortful cognitive deliberation, questions, and inquiry that aim to restore cognitive equilibrium. The affective state of confusion is diagnostic of cognitive disequilibrium (Graesser and Olde 2003; Graesser et al. 2007) and the resolution of the confusion is essential to restoring equilibrium.

Important Scientific Research and Open Questions

Recent, empirical evidence substantiates the predictions that confusion is related to learning. Craig et al. (2004) conducted an observational study in which confusion among other affective states (i.e., boredom, eureka, flow, frustration, and neutral) were observed during a learning session with an intelligent tutoring system. Of the observed affective states, confusion and flow displayed significant positive correlates with learning. Boredom was observed to be negatively correlated. Of the affective states, only confusion was observed to predict learning, accounting for 27% of the variance. Further, when learner's performance for sessions with and without confusion present was compared, significant differences were revealed. Participants in confusion-present sessions exhibited a 46% increase in learning (Cohen's $d = .64$) over participants with confusion-absent sessions.

However, the presence of confusion might not always produce ideal learning. Since confusion occurs during cognitive disequilibrium, the learner could either resolve the confusion and move back into a state of equilibrium or fail to resolve it. D'Mello and Graesser (2010) demonstrated this empirically using an offline self-report methodology. Under this methodology, learners viewed a video of their interaction with an intelligent tutor and indicated their affective states from a fixed list of affective states: Confusion, Boredom, Flow, Frustration, Delight, Surprise, and Neutral. They found that confusion states associated with more learning showed conflict resolution and thus a return to cognitive equilibrium of neutral or flow states. However, when participants exhibited confusion states that were not resolved they tended to transition to frustration and boredom and decreased learning.

When the learner is confused, there might be a variety of potential paths to pursue. The learner could be allowed to continue being confused during the cognitive disequilibrium (and the affiliated increased physiological arousal that accompanies all affective states). The learner's self-regulated thoughts might hopefully restore equilibrium when feedback to learner errors is delayed. Alternatively, after some period of time waiting for the learner to progress, indirect hints could be provided to nudge the learner into more productive trajectories of thought. However, the optimal paths have yet to be determined.

Cross-References

- ► Affective and Cognitive Learning in the Online Classroom
- ► Boredom of Learning
- ► Emotions: Functions and Effects on Learning
- ► Flow Experience and Learning

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Congruence

Congruence, realness, or genuineness is a most basic attitude for the facilitation of learning. It means that the feelings the facilitator is experiencing are available to his or her awareness, that he or she is able to live these feelings, to be them, and able to communicate them if appropriate (Rogers 1983).

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Conjunction

► Configural Cues in Associative Learning

Connectionism

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Synonyms

Artificial Neural network modeling; Connectionist modeling; Neural nets; Parallel Distributed Processing (PDP)

Definition

Connectionism is an interdisciplinary approach to the study of cognition that integrates elements from the fields of artificial intelligence, neuroscience, cognitive psychology, and philosophy of mind. As a theoretical movement in cognitive science, connectionism suggests that cognitive phenomena can be explained with respect to a set of *general* information-processing principles, known as parallel distributed processing (Rumelhart et al. 1986a). From a methodological point of view, connectionism is a framework for studying cognitive phenomena using architectures of simple processing units interconnected via weighted connections.

These architectures present analogies to biological neural systems and are referred to as *(Artificial) Neural Networks*. Connectionist studies typically propose and implement neural network models to explain various aspects of cognition. The term connectionism stems from the proposal that cognition emerges in neural network models as a product of a learning process which shapes the values of the weighted connections. Connectionism supports the idea that knowledge is represented in the weights of the connections between the processing units in a distributed fashion. This means that knowledge is encoded in the structure of the processing system, in contrast to the symbolic approach where knowledge is readily shifted between different memory registers.

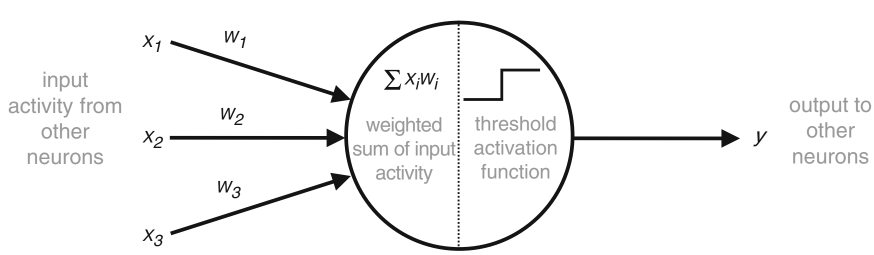
Theoretical Background

Artificial Neural Networks are abstract models of biological neural systems. They consist of a set of identical processing units, which are referred to as *artificial neurons* or *processing units*. Artificial neurons are interconnected via weighted connections.

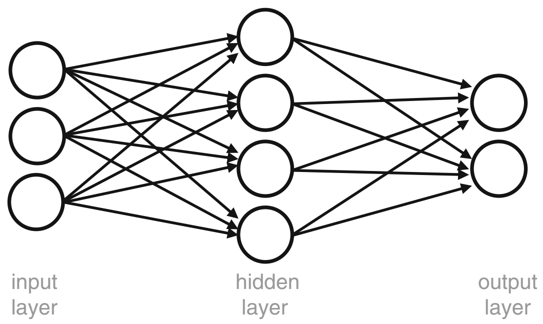
A great deal of biological complexity is omitted in artificial neural network models. For example, artificial neurons perform the simple function of discriminating between different levels of input activation. The *detector model* of the neuron (Fig. 1) is a crude approximation of the role of dendrites and synaptic channels in biological neurons. According to this model, each neuron receives a number of inputs from other neurons. The neuron integrates the inputs by computing a weighted sum of sending activation. Based on the value of the total input activation, an activation function (e.g., a threshold function) determines the level of the output activation of the neuron. The output activation is propagated to succeeding neurons.

The pattern of connectivity between the processing units defines the architecture of the neural network and the input–output functions that can be performed. The processing units are usually arranged in layers. It is notable that a layered structure has also been observed in neural tissues. Many different neural network architectures have been implemented in the connectionist literature. One that has been particularly common is the *three-layer feed-forward neural network* (Fig. 2). In this network, the units are arranged in three layers: input, hidden, and output. The connectivity is feed-forward, which means that the connections are unidirectional, and connect the input to the hidden, and the hidden to the output layer. The connectivity is also full: Every neuron of a given layer is connected to every neuron of the next layer.

A key property of neural networks is their ability to learn. Learning in neural networks is based on altering the extent to which a given neuron's activity alters the activity of the neurons to which it is connected. Learning is performed by a *learning algorithm* which determines appropriate changes in the weight values to perform a set of input–output mappings. For example, the *Backpropagation of Error* algorithm (Rumelhart et al. 1986b) can be used to train a feed-forward



Connectionism. Fig. 1 The detector model of the real neuron



Connectionism. Fig. 2 A three-layered feed-forward neural network with three units in the input layer, four units in the hidden layer, and two units in the output layer

multilayered network (Fig. 2) using *supervised* learning. For this type of learning, the learning algorithm presents the network with pairs of input patterns and desired output patterns (or targets). The algorithm computes the output error, i.e., the difference between the actual output of the network and the targets. Next, the algorithm propagates appropriate error signals back down through each layer of the network. These error signals are used to determine weight changes necessary to achieve the minimization of the output error. For a more detailed discussion of learning in neural networks, see connectionist theories of learning.

Other issues that are considered in neural network modeling concern the representation of the learning environment. For example, a *localist* or a *distributed* scheme can be used to represent different entities. In the former, a single unit is used to encode an entity, while in the latter an entity is encoded by an activation pattern across multiple units. Furthermore, the different input–output patterns which compose the learning environment can be presented in different ways (e.g., sequentially, randomly with replacement, incrementally, or based on a frequency structure).

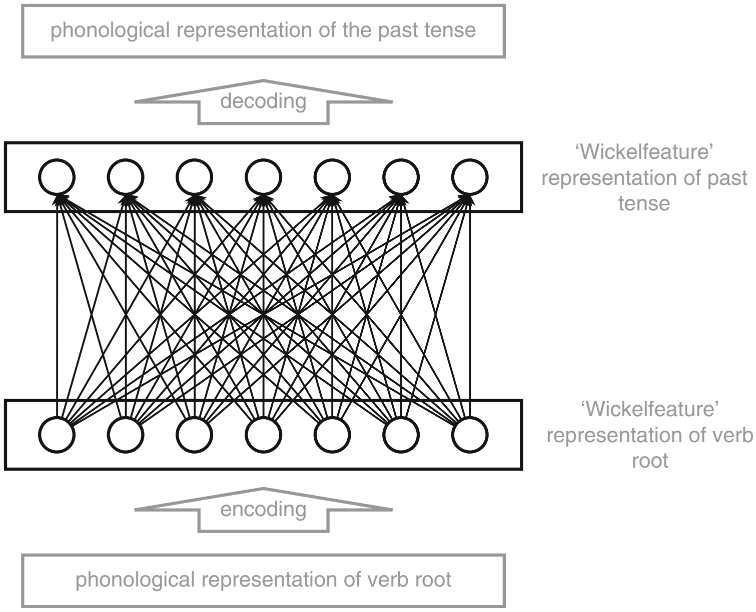
Important Scientific Research and Open Questions

The concept of neural network computation was initially proposed in the 1940s. However, the foundations for their systematic application to the exploration of cognition were laid several decades later by the influential volumes of Rumelhart, McClelland, and colleagues. Following this seminal work, a large number of studies proposed neural network models to address various cognitive phenomena.

Although connectionist models are inspired by computation in biological neural systems, they present a high level of abstraction. Therefore, they could not claim biological plausibility. Connectionist models are usually seen as cognitive models, which explain cognition based on general information-processing principles. One of the main strengths of connectionism is that the neural network models are not verbally specified but implemented. In this way, they are able to suggest elaborate mechanistic explanations for the structure of cognition and cognitive development. They also allow the detailed study of developmental disorders by considering training under atypical initial computational constraints, and acquired deficits by introducing 'damage' to trained models.

One of the most influential connectionist models is that of Rumelhart and McClelland (1986) for the acquisition of the English past tense (Fig. 3). The domain of the English past tense is of theoretical interest to psycholinguists because it presents a predominant regularity, with the great majority of verbs forming their past tenses through a stem-suffixation rule (e.g., walk/walked). However, a significant group of verbs form their past tenses irregularly (e.g., swim/swam, hit/hit, is/was). Rumelhart and McClelland trained a two-layered feed-forward network (a pattern associator) on mappings between phonological representations of the stems and the corresponding past tense forms of English verbs. Rumelhart and McClelland showed that both regular and irregular inflections could be learned by this network. Furthermore, they argued that their model reproduced a series of well-established phenomena in empirical studies of language acquisition. For example, the past tense rule was generalized to novel stems, while the learning of irregular verbs followed a U-shaped pattern (an initial period of error-free performance succeeded by a period of increased occurrence of *overgeneralization* errors, e.g., *think/thinked* instead of *thought*).

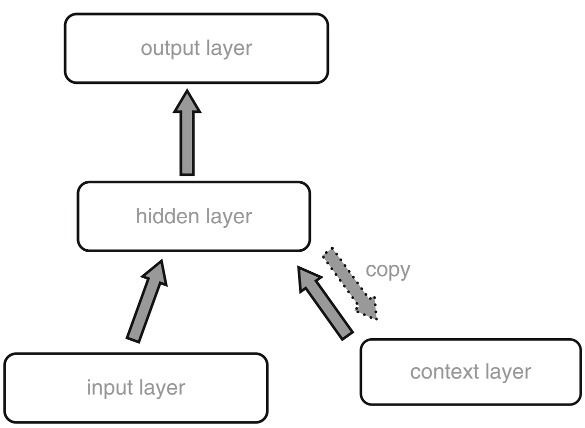
The success of this model in simulating the acquisition of the English past tense demonstrated that an explicit representation of rules is not necessary for the acquisition of morphology. Instead, a rule-like behavior was the product of the statistical properties of input–output mappings. The Rumelhart and



Connectionism. Fig. 3 The Rumelhart and McClelland (1986) model for the learning of the English past tense. The core of the model is a two-layered feed-forward network (pattern associator) which learns mappings between coarse-coded distributed representations (Wickelfeature representations) of verb roots and past tense forms

McClelland (1986) model posed a serious challenge to existing 'symbolic' views, which maintained that the acquisition of morphology was supported by two separate mechanisms, also referred to as the *dual-route model*. According to the dual-route model, a *rule-based system* was involved in the learning of regular mappings, while a *rote-memory* was involved in the learning of irregular mappings. A vigorous debate, also known as the 'past tense debate,' ensued in the field of language acquisition (c.f., Pinker and Prince 1988). By the time this debate resided, connectionist studies had moved on to addressing many aspects of the acquisition of past tense and inflectional morphology in greater detail. For example, Thomas and Karmiloff-Smith (2003) incorporated phonological and lexical-semantics information in the input of a three-layered feed-forward network and studied conditions under which an atypical developmental profile could be reproduced, as a way of investigating the potential cause of developmental language impairments.

Another important connectionist model is the simple recurrent network (SRN) proposed by Elman (1990). The significance of this network lies in its ability to represent time and address problems, which involve the processing of sequences. As shown in Fig. 4,



Connectionism. Fig. 4 The Simple Recurrent Network (Elman 1990)

the SRN uses a three-layered feed-forward architecture in which an additional layer of 'context units' is connected to the hidden layer with recurrent connections. Time is separated into discrete slices. On each subsequent time slice, activation from the hidden layer in the previous time slice is given as input to the network via the context layer. In this way, SRN is able to process a new input in the context of the full history of the previous inputs. This allows the network to learn statistical relationships across sequences in the input.

Acknowledgments

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Cross-References

► Computational Models of Human Learning
► Connectionist Theories of Learning
► Developmental Cognitive Neuroscience and Learning
► Human Cognitive Architecture
► Learning in Artificial Neural Networks
► Neural Network Assistants for Learning

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Connectionist Modeling

► Connectionism

Connectionist Models of Human Learning

► Computational Models of Human Learning

Connectionist Networks

► Learning in Artificial Neural Networks

Connectionist Theories of Learning

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Synonyms

Associative learning; Backpropagation of error algorithm; Correlational learning; Hebbian learning; Self-organizing maps

Definition

The majority or the connectionist theories of learning are based on the *Hebbian Learning Rule* (Hebb 1949). According to this rule, connections between neurons presenting correlated activity are strengthened. Connectionist theories of learning are essentially abstract implementations of general features of brain plasticity in architectures of artificial neural networks.

Theoretical Background

Connectionism provides a framework (Rumelhart et al. 1986a) for the study of cognition using Artificial Neural Network models. Neural network models are architectures of simple processing units (artificial neurons) interconnected via weighted connections. An artificial neuron functions as a detector, which produces an output activation value determined by the level of the total input activation and an activation function. As a result, when a neural network is exposed to an environment, encoded as activation patterns in the input units of the network, it responds with activation patterns across the units.

In the connectionist framework an artificial neural network model depicts cognition when it is able to respond to its environment with meaningful activation patterns. This can be achieved by modifications of the values of the connection weights, so as to regulate the activation patterns in the network appropriately. Therefore, connectionism suggests that learning involves the shaping of the connection weights. A learning algorithm is necessary to determine the changes in the weight values by which the network can acquire domain-appropriate input-output mappings.

The idea that learning in artificial neural networks should entail changes in the weight values was based on observations of neuropsychologist Donald Hebb on biological neural systems. Hebb (1949) proposed his *cell assembly theory* also known as *Hebb's rule* or *Hebb's postulate*:

- When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased. (1949, p.62)

Hebb's rule suggested that connections between neurons which present correlated activity should be strengthened. This type of learning was also termed *correlational* or *associative* learning.

A simple mathematical formulation of the Hebbian learning rule is:

$$\Delta W_{ij} = \eta a_i a_j \quad (1)$$

The change of the weight (Δw_{ij}) from a sending unit j to a receiving unit i should be equal to the constant η multiplied by the product of output activation values (α_i and α_j) of the units. The constant η is known as learning rate.

Important Scientific Research and Open Questions

Different learning algorithms have been proposed to implement learning in artificial neural networks. These algorithms could be considered as variants of the Hebbian rule, adjusted to different architectures and different training methods.

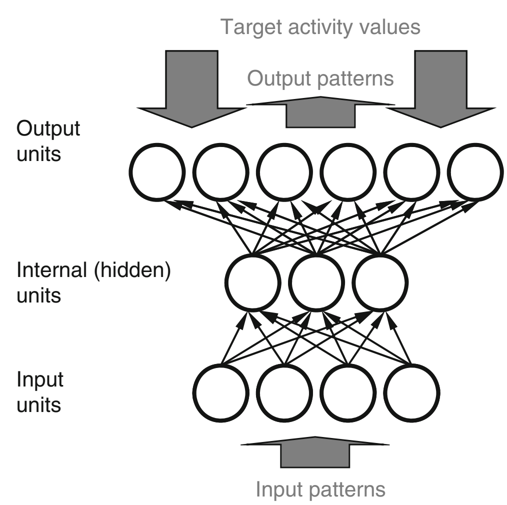
A large class of neural networks models uses a multilayered feed-forward architecture. This class of models is trained with *supervised learning* (Fig. 1). The environment is presented as pairs of input patterns and desired output patterns (or targets), where the target is provided by an external system (the notional "supervisor"). The network is trained on the task of producing the corresponding targets in the output when an input pattern is presented.

The *Backpropagation of Error* algorithm (Rumelhart et al. 1986b) as proposed for training such networks. Backpropagation is an error-driven algorithm. The aim of the weight changes is the minimization of the output error of the network. The Backpropagation algorithm is based on the *delta rule*:

$$\Delta W_{ij} = \eta (t_i - a_i) a_j \quad (2)$$

The delta rule is a modification of the Hebbian learning rule (Eq. 1) for neurons that learn with supervised learning. In the delta rule, the weight change (Δw_{ij}) is proportional to the difference between the target output (t_i) and the output activation of the receiving neuron (α_i), and the output activation of the sending neuron (α_j).

Backpropagation generalizes the delta rule in networks with hidden layers, as a target activation value is not available for the neurons on these internal layers. Internal layers are necessary to improve the computational power of the learning system. In a forward pass, the Backpropagation algorithm calculates the activations of the units of the network. Next, in a backward pass the



Connectionist Theories of Learning. Fig. 1 Supervised learning in a three-layered feed-forward neural network algorithm iteratively computes error signals (*delta terms*) for the units of the deeper layers of the network. The error signals express the contribution of each unit to the overall error of the network. They are computed based on the derivatives of the error function. Error signals determine changes in the weights which minimize the overall network error. The *generalized delta rule* is used for this purpose:

$$\Delta W_{ij} = \eta \delta_i a_j \tag{3}$$

According to this rule, weight changes equal to the learning rate times the product of the output activation of the sending unit (α_j) and the delta term of the receiving unit (δ_{ii}).

Although the Backpropagation algorithm has been widely used, it employs features which are biologically implausible. For example, it is implausible that error signals are calculated and transmitted between the neurons. However, it has been argued that since forward projections between neurons are often matched by backward projections permitting bidirectional signaling, the backward projections may allow the implementation of the abstract idea of the backpropagation of error.

Pursuing this idea, other learning algorithms have been proposed to implement error-driven learning in a more biologically plausible way. The *Contrastive Hebbian Learning* algorithm (Hinton 1989) is a learning algorithm for bidirectional connected networks. This algorithm considers two phases of training in each presentation of an input pattern. In the first one, known as the *minus phase* or *anti-Hebbian update*, the network is allowed to settle as an input pattern is presented to the network while the output units are free to adopt any activation state. These activations serve as *noise*. In the second phase (*plus phase* or *Hebbian update*), the network settles as the input is presented while the output units are clamped to the target outputs. These activations serve as *signal*. The weight change is proportional to the difference between the products of the activations of the sending and the receiving units in the two phases, so that the changes reinforce signal and reduce noise:

$$\Delta W_{ij} = \eta\left(a_i^{+} a_j^{+} - a_i^{-} a_j^{-}\right) \tag{4}$$

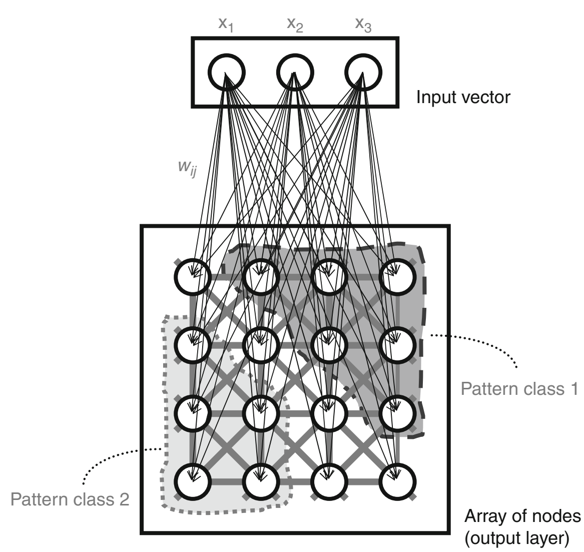
Learning is based on contrasting the two phases, hence the term Contrastive Hebbian Learning.

O'Reilly and Munakata (2000) proposed the LEABRA (Local, Error-driven and Associative, Biologically Realistic Algorithm) algorithm. This algorithm combines error-driven and Hebbian Learning, exploiting bidirectional connectivity to allow the propagation of error signals in a biologically plausible fashion.

The supervised learning algorithms assume a very detailed error signal telling each output how it should be responding. Other algorithms have been developed that assume less detailed information. These approaches are referred to as *reinforcement learning*.

Another class of neural networks is trained with *unsupervised learning*. In this type of learning, the network is presented with different input patterns. The aim of the network is to form its own internal representations which reflect regularities in the input patterns.

The Self-Organizing Map (SOM; Kohonen 1984) is an example of a neural network architecture that is trained with unsupervised learning. As shown in Fig. 2, a SOM consists of an *array of neurons* or *nodes*. Each node has coordinates on the map and is associated with a weight vector, of the same dimensionality as the input patterns. For example, if there are three dimensions in the input, there will be three input units, and each



Connectionist Theories of Learning. Fig. 2 Unsupervised learning in a simple self-organizing map (SOM) output unit will have a vector of three weights connected to those input units.

The aim of the SOM learning algorithm is to produce a topographic map that reflects regularities in the set of input patterns. When an input pattern is presented to the network, the SOM training algorithm computes the Euclidean distance between the weight vector and the input pattern for each node. The node that presents the least Euclidean distance (*winning node* or *best matching unit [BMU]*) is associated with the input pattern. Next, the weights vectors of the neighboring nodes are changed so as to become more similar to the weights vector of the winning node. The extent of the weight changes for each of the neighboring nodes is determined by its location on the map using a *neighborhood function*. In effect, regions of the output layer compete to represent the input patterns, and regional organization is enforced by short-range excitatory and long range inhibitory connections within the output layer. SOMs are thought to capture aspects of the organization of sensory input in the cerebral cortex. Hebbian learning to associate sensory and motor topographic maps then provides the basis for a system that learns to generate adaptive behavior in an environment.

Cross-References

► Adaptive Learning Systems
► Bayesian Learning
► Computational Models of Human Learning
► Connectionism
► Hebbian Learning
► Learning in Artificial Neural Networks
► Reinforcement Learning in Spiking Neural Networks
► Self-Organized Learning

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Conscientiousness

One of the big five personality factors. Individuals scoring high on this dimension tend to be organized and mindful of details.

Consciousness and Emotion: Attentive vs. Pre-attentive Elaboration of Face Processing

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Synonyms

Aware; Facial expression; Implicit elaboration; Unaware; Unconscious processing

Definition

Emotional facial expressions represent facial displays of emotions which determine different patterns of muscular correlates, cognitive responses, and brain activation. *Autonomic* and *central nervous systems* cooperate in order to provide a coherent pattern of mimic responses to specific contextual cues. *Positive* (i.e., happiness) vs. *negative* (i.e., anger) facial expressions are produced respectively in consequences to aversive or appetitive contexts. People are able to consciously produce and comprehend facial expressions, but in many cases, they may obtain emotional information from face by using an *unconscious processing* (*pre-attentive processing*). Typically, tasks that can be performed in less than 200 ms are considered pre-attentive. Simple features are extracted from the visual display in the pre-attentive system and later joined in the focused attention system into coherent objects. Pre-attentive processing is done quickly, effortlessly and in parallel. Taking advantage of pre-attentive processing can greatly improve intuitiveness of representations yielding in a faster and more natural way of acquiring information. Contrarily, conscious production and comprehension of facial expressions allow a more detailed and complete way of processing information, it being a serial and effortful way of take information.

Theoretical Background

Rapid detection of emotional information is highly adaptive, since it provides critical element on environment and on the attitude of the other people (Darwin 1872). Specifically, *motivational significance of emotions* has an effect on subjects' responses, since it was found that emotionally salient stimuli (unpleasant compared to neutral; more arousing compared to less arousing) generate greater magnitude cognitive, cortical, and autonomic system responses. Thus, significance of emotional facial expressions in terms of the relevance of the emotional patterns for the subjective safeguard influences the degree of attentional resources allocated.

It was showed that each emotion and its facial expression represents a specific response to a particular kind of significant event, that is it is evaluated by the subject in line with its motivational significance. This ► appraisal process is regulated by two main criteria: the arousing power of the stimulus (high or low); the ► valence of the emotional stimulus (positive or negative) (Russell 2003). Thus, the entire emotional universe is representable by the two axes, and the "significance" attributed to the emotional expressions may have a direct effect on the cognitive level and the degree of attention allocated.

Moreover, significant affective processes happen *outside consciousness* (LeDoux 1996). It has been shown that the affective information contained in facial expression is perceived involuntarily, and is able to constrict automatically the focus of attention. Information presented under the conscious threshold may be processed on a high level even if the subject is unaware of this information, since pre-attentive response to emotional faces is effective in eliciting coherent subjective responses. Two main factors seem to be relevant in orienting subject's response to the emotional cues in case of unconscious stimulation: the content of the stimulus and the subjective predisposition to respond to emotional situations. This fact is in line with previous research that have used autonomic (skin conductance measures or cardiovascular indexes) measures or ► conditioned responses, that pointed out unconscious affective stimuli may have effect for the appraisal of conscious stimuli. It seems that the information presented under pre-attentive conditions may be perceived and cognitively processed. For this reason, facial expressions of emotion are considered unique in their ability to orient the subjective cognitive resources, even if people are unable to process information consciously.

Also the responses to unconscious stimulation showed to be sensitive to the emotional content of the facial stimuli, as revealed by different behavioral and physiological measures. That is, it was hypothesized that subjects are able to assign a *semantic value* to the emotional content of faces even in an unaware condition. Unconsciously processing for facial stimuli can also be demonstrated in clinical context, such as in case of prosopagnosia. In most cases, prosopagnosics appear to recognize familiar faces even though they fail to identify the persons verbally. Therefore, the patients showed an unconscious recognition that cannot be accessed consciously (Tranel and Damasio 1985).

Similarities in processing between attentive vs. pre-attentive stimulation can also be assessed from neural point of view: Consistent analogies in the aware and unaware processing structure were well-founded, suggesting that similar neural activity is involved. In humans, evidence for the unconscious perception of emotional face has been revealed in terms of subjective reports, autonomic reactions, brain imaging measure, as well as ERPs (event-related potentials) and brain oscillations. Brain areas generally involved in evaluation of the emotional and motivational significance of facial expressions appear to be mediated by the amygdala and orbitofrontal cortex, while structures such as the anterior cingulate, prefrontal cortex, and somatosensory areas are linked to the conscious representation of emotional facial expression for the strategic control of thought and action (Adolphs 2003).

Important Scientific Research and Open Questions

Numerous studies have sought to demonstrate that emotional information can be perceived without awareness. The conclusion that emotional facial expressions can be perceived without consciousness is not surprising given the importance of emotional information for human survival. Nevertheless, although the existence of unconscious affect elaboration was accepted, the question concerning its relevance for emotional decoding is still open. Specifically, what remains unclear was the specific semantic value this perception has and in what measure the subject can elaborate the unconscious emotional stimuli.

Only a limited number of studies have explored the significance of conscious vs. unconscious face comprehension, based on ► priming effect or subliminal stimulation. The short stimulus presentation in pre-attentive condition prevents the subjects to have a clear cognition of the stimulus. Generally, an objective threshold for pre-attentive condition is provided. It was defined by an identification procedure, the case where stimulus is perceived by the subject no more than in 50% of the times. According to signal detection theory (SDT), when detection threshold sensitivity is at chance ($d' = 0$), it is unlikely that there is conscious awareness of the stimulus.

Moreover, another useful measure to analyze conscious and unconscious perception of faces is the masking procedure. By low intensity and brief exposure, a target stimulus can be made unrecognized when another stimulus is presented simultaneously, shortly before (*forward masking*), or shortly after (*backward masking*). This paradigm is used to investigate below awareness response to emotional perception in which facial expressions are followed immediately by a masking face. Evidence for the unconscious perception of masked faces has been revealed in terms of subjective reports, autonomic activity, and functional brain imaging measures. Nevertheless, the effect of this masking technique was not largely used for the emotional face detection, and there is no precise knowledge of the actual effect of masked emotional stimulus on the elaboration of the target one.

Most of the recent research on the detection and analysis of emotionally significant information from face have used fMRI (functional Magnetic Resonance Imaging) measures, which are based on relatively slow hemodynamic brain responses, and the studies on the time course of emotional processing have been relatively scarce. Thus, these methods need to be completed with measures that provide insights into temporal parameters of unconscious emotional comprehension, such as ERP. Specifically, ERP measures are very useful tools to examine the time course of the conscious vs. unconscious stimulus elaboration at a very high temporal resolution (Balconi and Mazza 2009). ERPs furnish a valid measure of the qualitative nature of the emotional mechanisms, checking the resemblance of the underlying processes for attentive and not attentive emotional elaboration. For this reason, it is interesting to compare ERP profiles in conscious vs. unconscious condition, in order to verify the similarity of the comprehension processes. Therefore, the main topics to be explored in the future about attentive vs. pre-attentive processing are related to the *semantic significance* of unconsciously processed emotional stimulus. Specifically:

– The resemblance of the two processes, attentive and pre-attentive, from a qualitative point of view
– The existence of some differences in terms of the type and the amount of cognitive resources required to activate the two processes
– The temporal course of these mechanisms, with a delayed or anticipated effect for unconscious elaboration
– The resemblance of attentive vs. pre-attentive process in response to different emotional facial expressions

Cross-References

► Attention and Implicit Learning
► Emotional Mental Models
► Emotional Schema(s)
► Explicit Versus Implicit Learning

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Consensus Learning

► Brainstorming and Learning

Consolidation

The time-dependent strengthening of a memory after a training trial (or trials) that results from biological processes in the brain.

Cross-References

► Covert Reorganization / Spatial Learning

Constraint Networks

A constraint network is a set of variables and constraints that interrelate and define the valid values for the variables. Constraint networks have proven to be a useful mechanism for modeling computationally intensive tasks in artificial intelligence. They operate by expressing a problem as a set of variables, variable domains, and constraints and define a search procedure that tries to satisfy the constraints by assigning values to variables from their specified domains.

Constraint Satisfaction for Learning Hypotheses in Inductive Logic Programming

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Synonyms

Template consistency problem

Definition

Inductive logic programming is a subfield of machine learning which uses first-order logic as a uniform representation of examples, background knowledge, and hypotheses. In many works, it is assumed that examples are clauses and the goal is to find a consistent hypothesis H, that is, a clause entailing all positive examples and no negative example. Entailment is frequently checked using θ-subsumption which is a decidable restriction of logical entailment. Given a clause T called a template, the template consistency problem deals with finding a substitution σ such that $H = T\sigma$ is a consistent hypothesis. Both entailment checking and template consistency problems are combinatorial problems that can be solved using constraint satisfaction techniques.

Theoretical Background

In the core form, Inductive Logic Programming (ILP) deals with the problem of finding a hypothesis covering all positive examples and excluding negative examples (Muggleton and De Raedt 1994). For the sake of complexity analysis, a formalization of core ILP tasks was proposed by the seminal paper (Gottlob et al. 1999). Gottlob defines two basic ILP problems: the bounded consistency problem and the template consistency problem. In both, it is assumed that examples are clauses and the goal is to find a consistent hypothesis H, that is, a clause entailing all positive examples and no negative example. Entailment is checked using θ-subsumption (Plotkin 1970) which is a decidable restriction of logical entailment. For simplicity of notation, we can assume clauses to be expressed as sets of literals, and, without loss of generality, we can only work with positive literals, that is, non-negated atoms. All terms in the learning examples (hypotheses, respectively) are constants (variables) written in the lower (upper) cases. For instance, $E = \{\mathrm{arc}(a,b), \mathrm{arc}(b,c), \mathrm{arc}(c,a)\}$ is an example and $H = \{\mathrm{arc}(X,Y), \mathrm{arc}(Y,Z)\}$ is a hypothesis. Hypothesis H *subsumes* example E, if there exists a substitution θ of variables such that $H\theta \subseteq E$. In the above example, substitution $\theta = \{X/a, Y/b, Z/c\}$ implies that H subsumes E.

In the bounded consistency formulation, the number of literals in H is polynomially bounded by the number of examples. In the template consistency formulation, it is instead required that $H = T\sigma$ for some substitution σ, where T is a given clause called a *template*. Since all terms in H are supposed to be variables, the task lies in determining which subsets of variables in T should be unified. For generality, we assume that all variables in T are mutually different, that is, each variable occurs exactly once in T, as in $T = \{\text{arc}(X_1,X_2), \text{arc}(X_3,X_4)\}$. An exemplary hypothesis H may be obtained from this T by applying unification $X_2 = X_3$ (and then suitably renaming the variables). Clearly, if no unification is applied and the template consists only of the predicates in the example (arc/2 in our case) then the hypothesis subsumes that example. The reason for introducing unifications is thus to prevent H from subsuming negative examples. In our case, hypothesis obtained by applying unifications $X_2 = X_3$ and $X_1 = X_4$ to T does not subsume the above example E.

Gottlob shows that both bounded consistency and template consistency problems are equivalent in terms of computational complexity and belong among Σ_2^P complete problems. In both cases, the complexity arises from two sources:

1. "The subsumption test for checking whether a clause subsumes an example"
2. "The choice of the positions of variables in the atoms (of the clause)"

Informally, (2) corresponds to the task of searching the space of admissible clauses, and (1) corresponds to evaluating an explored clause. Both task (1) and (2) can be solved using constraint satisfaction techniques.

Constraint satisfaction problem (CSP) is a triple (X, D, C), where X is a finite set of decision variables, for each $x_i \in X$, $D_i \in D$ is a finite set of possible values for the variable x_i (the domain), and C is a finite set of constraints (Dechter 2003). A constraint is a relation over a subset of variables (its *scope*) that restricts the possible combinations of values to be assigned to the variables in its scope. The constraints can be expressed in extension using a set of compatible value tuples. A *solution to a CSP* is a complete instantiation of variables such that the values are taken from respective domains and all constraints are satisfied. Constraint satisfaction techniques are frequently based on the combination of inference techniques and search. The most widely used inference technique is arc consistency (the name goes from the graph representation of a CSP, where nodes describe the variables and arcs specify the constraints). The constraint is arc consistent if all values in the domains of constrained variables have some support in the constraint; in particular, the value is part of a tuple satisfying the constraint. The values without a support are removed from the variables' domains. For example, the constraint $A=B$, where the domain of A is {1,2} and the domain of B is {1,2,3}, is made arc consistent by removing value 3 from the domain of B. If any domain becomes empty then the problem has no solution. If all the constraints are arc consistent and the domains are still not singleton then some variable is selected, its domain is split into two (or more) disjoint subsets, and the obtained subproblems are solved using the same technique. This domain splitting forms a choice point in the search procedure. Other branching strategies exist, for example, taking some constraint in the form of exclusive disjunction such as $C \vee C'$ and adding C to the problem in one search branch and C' to the problem in the second search branch. An optimization version of a CSP called a Constraint Optimization Problem (COP) adds a objective function that evaluates the solutions. The task is to find a solution to a CSP that minimizes (or maximizes) the value of the objective function.

Important Scientific Research and Open Questions

Maloberti and Sebag (2004) used constraint satisfaction techniques to address the above complexity source (1). In particular, they proposed a θ-subsumption algorithm called *Django* that is based on reformulation of θ-subsumption as a binary constraint satisfaction problem. Thanks to powerful CSP heuristics, Django brought dramatic speed-up for θ-subsumption and consequently for the entire ILP system. The constraint model for each example looks as follows. First, for each predicate symbol p with arity k we collect all k-tuples of values from atoms of this predicate in the example. These value tuples define in extension a k-ary constraint c_p. Now, for each atom of predicate p with variables $\{Y_1,\ldots, Y_k\}$ in the hypothesis we post constraint c_p over these variables. Clearly, based on instantiation of variables $\{Y_1,\ldots, Y_k\}$ we can find an atom in the example to which a given atom from the hypothesis is mapped to. Let $\{\text{arc}(a,b), \text{arc}(b,c), \text{arc}(c,a)\}$ be all atoms of predicate arc/2 in the example. Then binary constraint c_{arc} is defined in extension by a set of value pairs $\{(a,b), (b,c), (c,a)\}$. Atom arc(X,Y) from the hypothesis is represented by constraint $c_{arc}(X,Y)$ and instantiation $X=a$, $Y=b$ means that that this atom is mapped to arc(a,b) in the example. In summary, any solution to a CSP defined by constraints c_p describes a substitution θ such that $H\theta \subseteq E$. The following example demonstrates the constraint model for the subsumption problem (let us call it a *subsumption model*):

Example:	
arc(a,b), arc(b,c), arc(c,a), red(a), red(c)	
Hypothesis:	
arc(Y_1,Y_2), arc(Y_2,Y_3), red(Y_2)	
Subsumption model:	
Variables	Y_1, Y_2, Y_3
Domains	$\{a,b,c\}$
Constraints	$c_{arc}(Y_1,Y_2)$, $c_{arc}(Y_2,Y_3)$, $c_{red}(Y_2)$
Solutions	$\{Y_1=c, Y_2=a, Y_3=b\}$, $\{Y_1=b, Y_2=c, Y_3=a\}$

To address the above complexity source (2) Barták (2010) proposed a constraint model and dedicated search strategy for specifying which variables in the template should be unified to obtain a consistent hypothesis. Recall that each variable appears exactly once in the template so one can order the variables. Indices in the following example show this ordering $T = \{\text{arc}(X_1,X_2), \text{arc}(X_3,X_4), \text{arc}(X_5,X_6)\}$. The model is based on the observation that if a set of variables is unified then we can select the variable with the smallest index to represent this set and all other variables in the set are mapped to this variable. For example, unification $X_2=X_3$ can be represented by mapping X_3 to X_2. The constraint model uses index variable I_i for each variable X_i in the template to describe the mapping. The domain of I_i is $\{1,\ldots,i\}$ (variable X_i can only be mapped to itself or to some preceding variable). To express that variables X_i and X_j are unified we simply post a constraint $I_i = I_j$ (both variables are mapped to an identical variable). To ensure that each variable is mapped to the first variable in the set of unified variables we use a constraint

$$\forall i = 1, \ldots, n \; element(I_i, [I_1, \ldots, I_n], I_i),$$

where n is the total number of variables (in constraint *element*(X,List,Y) X and Y are variables and L is list of variables; the constraint describes a relation that Y equals to the X-th element of List.). In other words, if variable X_i is mapped to X_j ($I_i = j$) then X_j is not mapped to any preceding variable ($I_j = j$, i.e., $I_{Ii} = I_i$). For example, [1,1,2] is not a valid list of indices (it represents $X_1 = X_2$ and $X_2 = X_3$), the correct representation of this unification should be [1,1,1] ($X_1 = X_2$ and $X_1 = X_3$). The *element* constraints thus ensure that each set of unifications is represented by a single list of indices. The following example demonstrates the base *unification model*:

Template:	
arc(X_1,X_2), arc(X_3,X_4), arc(X_5,X_6), red(X_7), red(X_8), red(X_9), green(X_{10})	
Unification model:	
Variables	$I_1, \ldots, I_{10}$
Domains	$D_i = \{1,\ldots,i\}\ \forall i = 1,\ldots,10$
Constraints	$element(I_i, [I_1,\ldots, I_{10}], I_i)\ \forall i = 1,\ldots,10$

The unification model needs to be connected to the subsumption models for individual examples. This can be done again via the element constraints in the following way. Assume that n is the number of variables in the template. Then for each example E_j we plug a set $X_{j,1},\ldots, X_{j,n}$ of fresh variables into H, where these variables participate in the subsumption model for problem E_j. Note that each example may define different compatible tuples for the constraints and hence a different solution (subsumption) θ_j. The constraints $element(I_i, [X_{j,1},\ldots, X_{j,n}], X_{j,i})$ ensure that the variables in the subsumption models are properly unified based on the decision about unifications done in the unification model. These constraints can be posted in advance all together as we require all positive examples to be subsumed. However, for the negative example, we require that the corresponding CSP has no solution. This can be ensured by trying to solve the CSP for the negative example (while respecting the so far decided unifications) and if there is any solution found, this solution is broken by additional unification introduced to the unification model (which is immediately propagated to the constraint models for positive examples to validate whether it does not conflict the positive examples). The following algorithm scheme shows how the search strategy is integrated with the constraint models:

1. Generate a unification model with index variables I
2. *For each* positive example *p do*
   (a) Generate a subsumption model with fresh hypothesis variables X_p.
   (b) Connect hypothesis variables X_p to index variables.
3. *For each* negative example *e do*
   (a) Generate a subsumption model with fresh hypothesis variables Y_e.
   (b) Connect hypothesis variables Y_e to index variables.
   (c) *While* exists instantiation θ of hypothesis variables Y_e *do.*
      (i) Select variables $Y_{e,i}$ and $Y_{e,j}$ such that $Y_{e,i}\theta \neq Y_{e,j}\theta$.
      (ii) Introduce *choice point* $I_i = I_j$ or $I_i \neq I_j$.
   (d) Remove the variables Y_e with corresponding constraints.
4. Instantiate index variables *I*.
5. *For each* positive example *p do.*
   (a) Instantiate hypothesis variables X_p.

Further improvements of the base unification model were proposed (Barták 2010) such as symmetry breaking (the base model assumes the template to be a list of atoms while it is a set of atoms which introduces symmetrical solutions), stronger consistency techniques (global reasoning over equality and inequality constraints introduced in step (3-a-ii)), and hints in the form of forbidden unifications derived from the positive examples.

The above models were proposed for a strict separation of positive and negative examples. In practice, for example, due to noisy data, this is not possible and the task is stated differently – for example, to maximize the number of covered positive examples while minimizing the number of covered negative examples. The open question is whether the proposed models can be updated by exploiting constraint optimization technology for solving this modified problem. Another open question is how to effectively obtain the template. A straightforward approach is to incrementally build the template by adding predicates to it, but this seems too inefficient for practical problems.

Acknowledgments

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Cross-References

▶ Inductive Logic Programming
▶ Learning Algorithms
▶ Machine Learning

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Constraints on Learning

▶ Biological or Evolutionary Constraints on Learning

Constructing Meaning

▶ Historical Thinking

Construction of Schemas

▶ Schema Development

Constructionist Thinking

▶ Learning in Practice (Heidegger and Schön)

C

Constructive Alignment

A form of outcomes-based education that outlines the Intended Learning Outcomes (ILOs) of a course in terms of a verb that states what the learner is supposed to be able to do with the content taught. That verb denotes a learning activity that teaching needs to activate if the outcomes are to be optimally achieved. Assessment tasks likewise need to embody the verbs in the ILOs, together with assessment rubrics, that enable judgements to be made about how well the students achieve the intended learning outcomes.

Cross-References

► Aligning the Curriculum to Promote Learning

Constructive Induction

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Synonyms

Concept formation

Definition

Constructive induction is a process of inducing a concept definition that employs expansion of terminology.

Terminology is a collection of specialized terms that describe observations. Observations consist of concept examples (units) and examples of other comparable concepts. Concept definition is the generalization of the collection of observations. Taking origin in concept examples, concept definition specifies the distinguishing characteristics of the units, and indicates the domain of observations in which they were differentiated. The expanding terms are better suited to both differentiate and characterize the concept. Their construction involves process of concept formation.

Theoretical Background

Epistemologically, "a *concept* is a mental integration of two or more units which are isolated according to a specific characteristic(s) and united by a specific definition. The units involved may be any aspect of reality; entities, attributes, actions, qualities, relationships, etc.; they may be perceptual concretes or other, earlier-formed concepts. The act of isolation involved is a process of *abstraction*: i.e., a selective mental focus that takes out or separates a certain aspect of reality from all others (e.g., isolates a certain attribute from the entities possessing it, or a certain action from the entities performing it). The uniting involved is not a mere sum, but an *integration*, i.e., a blending of the units into a *single*, new *mental* entity which is used thereafter as a single unit of thought (but which can be broken into its component units whenever required)" (Rand 1990).

Concept learning has been an active research area in machine learning, a scientific discipline that is concerned with design and development of computer systems to simulate human thought processes (Michalski 1983). The main goal of concept learning is derivation of generalized concept descriptions from observations in order to facilitate concept recognition. Concept recognition identifies a learned concept that a given observation appertains. In congruence with the epistemological description of a concept formation process, computer-based concept learning modeling starts with a substantial assumption concerning observations, namely, the observations are already abstracted and contained within a well-defined domain using specific terminology, that is, representation space. For example, one of the early concept learning tasks was learning descriptions of eastbound and westbound trains (Michalski 1978) from five examples in each category, described in terms of eleven descriptors, such as car-shape, in front of, contains load, length, and number of wheels. The human-based process of abstracting this task for concept learning involved not only separating the concept of trains from other concepts but also made various abstractions of specific descriptors (car features, relationships, etc.).

Constructive induction is a process of learning a concept definition that involves two intertwined searches: one for the best representation space, and the second for the best concept definition in that space. It can be viewed as an adaptive process of self-improving the representation space by constructing additional descriptors aligned with the learning task at hand. The new descriptors are supporting concepts that focus on better distinguishing characteristics of the target concept. This incremental process involves the three-step concept formation cycle, that is, the abstraction, integration (generalization), and assigning a concept definition/name, which introduces a new concept (descriptor).

A fundamental role in the constructive induction process plays the representation space, as it provides context for learned concept definitions. The target concept never changes. Its definition does change according to essential characteristics found in the space. In the formation of any concept, the capability of making comparisons among observations is critical. In this context, "similarity is the relationship between two or more observations that possess the same characteristics but in different measure or degree" (Rand 1990).

The process of abstraction can be realized by many methods capable of conceptually clustering (grouping, agglomerating, sorting) observations. The need and complexity for abstracting depends on the current state of the representation space: starting with empty representation space (with no observations and no descriptors) to fully developed, that is, having examples described in terms of relevant descriptors, where it is a matter of selecting terms for building consistent and complete descriptions with regard to the learning task.

Constructive induction term was first used in machine learning, specifically in the context of concept learning from examples (Michalski 1978). Constructive induction systems may employ different strategies for generating new descriptors. Based on the primary strategy employed, the systems can be divided into four categories: data-driven, hypothesis-driven, knowledge-driven, and multistrategy (Wnek and Michalski 1994). Data-driven constructive induction systems analyze and explore the observations, including the interrelationships among their descriptors, and on that basis introduce changes in the representation space. Hypothesis-driven constructive induction systems incrementally transform the representation space by analyzing inductive hypotheses generated in one iteration and then using detected patterns as attributes for the next iteration. Knowledge-driven constructive induction systems apply expert-provided domain knowledge to construct new terms. Multistrategy constructive induction systems combine different approaches and methods for constructing new terms. Real-world applications of constructive induction systems utilize relational or textual databases as sources of observations, and use propositionalization, a form of abstraction, and aggregation techniques to transform representation space (Kietz and Morik 1994; Perlich and Provost 2006).

Important Scientific Research and Open Questions

Independent of the strategy for generating new descriptors is control over conceptual vocabulary. Machine learning methods can surely benefit from human experience in this regard, where philosophy is the foundation of science, and epistemology is the foundation of philosophy. The requirements of cognition determine the objective criteria of conceptualization. They can be summed up best in the form of an epistemological "razor": *concepts are not to be multiplied beyond necessity* – the corollary of which is; *nor are they to be integrated in disregard of necessity* (Rand 1990).

Another challenge for constructive induction is naming of constructed concepts. The challenge is not in assigning a name, as such can easily be generated by a computer program, rather assigning a meaningful name, understandable in human language. This might require some human–computer interaction to allow understanding of concept definition or the factors that contributed to differentiation of concept examples from other examples and then scope of generalization of the selected concept examples.

The underlying premise included in the above challenges is the need for maintaining synergy in human–computer interaction to preserve consistency in modeling real-world problems.

Cross-References

- ► Concept Learning
- ► Conceptual Clustering
- ► Feature Selection (Unsupervised Learning)
- ► Inferential Theory of Learning
- ► Machine Learning
- ► Multistrategy Learning

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Constructivism

This epistemology is based on the premise that learning is collaborative, learner centered, and requires activity from the learner without the primary need for an authoritative provider of information in the form of a teacher. The teacher becomes instead a catalyst or coach in organizing learning activities.

Cross-References

► Humanistic Approaches to Learning

Constructivism: Sociocultural Approaches

► Meaning Development in Child Language: A Constructivist Approach

Constructivist Agents

► Anticipatory Learning Mechanisms

Constructivist Learning

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Synonyms

Effective learning; Meaningful learning

Definition

The word *constructivist* is an adjective that comes from the noun *constructivism* which specifies the theory about the nature of reality and the theory of knowledge (epistemology) founded on the basis that humans generate knowledge and meaning from their experiences, mental structures, and beliefs that are used to interpret objects and events. Constructivism focuses on the importance of the individual knowledge, beliefs, and skills through the experience of learning. It states that the construction of understanding is a combination of prior knowledge and new information. Individuals can accept new ideas or fit them into their established views of the world. *Constructivist learning* is a theory about how people learn. It states that learning happens when learners construct meaning by interpreting information in the context of their own experiences. In other words, learners construct their own understandings of the world by reflecting on their experiences. Constructivist learning is related with pedagogic approaches that promote *active learning, effective learning, meaningful learning, constructive learning*, and *learning by doing*.

Theoretical Background

Constructivist learning has emerged as a prominent approach to learning and teaching on the basis of the work by John Dewey (1858–1952), Jean Piaget (1896–1980), Lev Vygotsky (1896–1934), Jerame Bruner (1915–), Maria Montessori (1870–1952), and Ernst von Glasersfeld (1917–), who, among others provide historical precedents for *constructivist learning theory. Constructivist learning* claims that learners do not just absorb information. Instead, learners construct information by actively trying to organize and make sense of it in unique ways.

In the literature of constructivism in education, there are many types of paradigms including cognitive/personal constructivism, social constructivism, radical constructivism, critical constructivism, cultural constructivism, genetic epistemology, constructionism, information-processing constructivism, interactive constructivism, cybernetic systems, and sociocultural approaches to mediated action. Although there are many paradigms with different emphases, they share many common perspectives about teaching and learning. These common perspectives provide the basis for constructivist learning.

Constructivist learning is articulated in contrast to *objectivist learning*. Jonassen (1999) compares objectivist conceptions of learning by constructivist conceptions of learning:

> ▶ Objectivist conceptions of learning assume that knowledge can be transferred from teachers or transmitted by technologies and acquired by learners. Objectivist conceptions of instructional design include the analysis, representations, and resequencing of content and tasks in order to make them more predictably and reliably transmissible.
>
> Constructivist conceptions of learning, on the other hand, assume that knowledge is individually constructed and socially coconstructed by learners based on their interpretations of experiences in the world. Since knowledge cannot be transmitted, instruction should consist of experiences that facilitate knowledge construction. (p. 217)

Objectivist learning expects that teachers transmit knowledge and learners replicate the presented content and gain the same understanding as the teacher (Jonassen 1999). Objectivist learning approach assumes that learner can gain the same understanding when systematic rules are used for logical conclusion. Therefore, objectivist learning does not provide appropriate training for creative thinking, higher-order problem solving, transferring and applying knowledge to concrete experiences. On the other hand, *constructivist learning* provides an opportunity for reflection and critical thinking to make sense of the world and create understanding, not just the memorizing of right answers (Brooks and Brooks 1999). Learning is a search for meaning, which requires understanding of the whole content as well as its parts, so the learning process focuses on individual understanding, not isolated facts (Brooks and Brooks 1999).

Two major types of the constructivist learning perspectives are *cognitive constructivism* and *social constructivism*. While Piaget (1973) developed the cognitive constructivism view of learning, Vygotsky (1978) developed the social constructivism view of learning. These two constructivist view of learning are different in emphasis, but there is also a great deal of overlap between them. Vygotsky shares many of Piaget's assumptions about how children learn, but Vygotsky puts more emphasis on the social context of learning.

The major foundation for cognitive constructivist approaches to teaching and learning is *Piaget's theory of cognitive development* (1973), which describes how children develop cognitive abilities. Piaget's theory of cognitive development (1973) has two major parts: ages and stages. According to Piaget there are four stages through birth to 12 years: the sensorimotor period (birth to 2 years), preoperational thought (2–6/7 years), concrete operations (6/7–11/12 years), and formal operations (11/12 to adult). According to Piaget (1973), learners must construct their knowledge through experiences by relying on ▶ cognitive structure (i.e., schemas and mental models). These cognitive structures are changed and enlarged through three complementary processes of ▶ assimilation, ▶ accommodation, and correction. Within Piagets's theory (1973), the basis of learning is discovery: "To understand is to discover, or reconstruct by rediscovery, and such conditions must be complied with if in the future individuals are to be formed who are capable of production and creativity and not simply repetition" (Piaget 1973, p. 20).

Social constructivism suggests that reality takes on meaning which is formed and reformed through the social process. *Vygotsky's constructivist theory* (1978), which is called social constructivism, emphasizes the importance of culture and social context for cognitive development. *Vygotsky's zone of proximal development* (1978) concept argues that learners can master concepts, which they cannot understand on their own, with help from instructors and peers. Vygotsky (1978) divides the child's language development into three stages (at age 2, 3, and 7). In each stage, the child learns through observing and interacting with his/her immediate social environment. According to Vygotsky (1978), the culture provides the cognitive tools to the child for development such as cultural history, social context, language, and technology. Adults such as instructors and parents guide learning by means of these cognitive tools. The type and quality of these tools play an important role on learning and development.

Like Piaget and Vygotsky, Bruner studied cognition and language learning in young children and defined learning as an active process in which a learner constructs new ideas or concepts based upon his/her both current and past knowledge by selecting and transforming information, constructing hypotheses, and making decisions through representing individual experiences in a cognitive structure (Brooks and Brooks 1999). In the constructivist classroom, the instruction should be surrounded by an active dialog between the instructor and student while the instructor tries to encourage students to discover principles by themselves. Therefore, the role of the instructor is to translate information to be learned into a format appropriate to the learner's level of understanding so that the student constantly builds upon what he/she has already learned.

Dewey (1966) is a reformer in educational policy. He emphasizes that schools should not focus on repetitive, rote memorization and that they should be engaged in real-world, practical training to be able to demonstrate their knowledge through creativity and collaboration. Dewey's book "Democracy and Education" (1966) states that processes of instruction should focus on the production of good habits of thinking so that students should have opportunities to think themselves and articulate their thoughts. According to Dewey, students should be involved in meaningful activities and apply the concepts they are trying to learn. Dewey (1966) uses term active learner by stressing that learning is an active process in which the learners construct their own meaning. In other words, learning is not a passive acceptance of presented knowledge by teachers, but is constructing meaning. Constructing meaning happens in the mind; therefore, educators should design both hands-on activities and mental activities. Dewey (1966) emphasizes that learning happens through reflective activities as a product of critical thinking. Learners should reflect on what they understand.

According to von Glasersfeld (1996), the human mind can only know what the human mind has made. In *radical constructivist* approach, there is an important point that how we know is more essential than what we know. There are two main principles of radical constructivism (von Glasersfeld 1996): (1) knowledge is not passively received but actively built up by subject; (2) cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality.

In summary, constructivist learning emphasizes that people construct their own understanding of the world, so people create their own mental models to make sense of their experiences. Also, constructivist learning emphasizes that the social and cultural context has a huge impact on learning. Therefore, learning is defined as a social process in which learners share, compare, and reformulate ideas to restructure new understandings. If an instruction or training allows learners to exchange their personal views and test them with others', learners can build their own understandings with empirical evidence through activities and observations. Since learners' level of potential development has a critical impact on understanding, learners' cognitive maturity, their interests, previous experiences should be considered in instructional design besides their social, cultural, and other contextual characteristics. Therefore, constructivist learning is defined as both an individual and a social process.

Important Scientific Research and Open Questions

Constructivist learning views learning as a social activity. Learning is influenced by social interaction and the language that the learner uses. Besides social interaction and language, other major factors that influence learning is learner's pervious knowledge, learner's motivation, and learner's characteristics such as beliefs, prejudices, and fears. These factors are associated with individual, social, and cultural aspects of learning. Constructivist learning requires educators to think about epistemology and pedagogy to be able to allow learners construct knowledge individually and socially. In order to teach well, educators must understand the mental models to support and challenge the learner's thinking (Brooks and Brooks 1999). Brooks and Brooks (1999) list 12 characteristics for teaching by implementing constructivist learning theory into classroom instruction:

- Encourage and accept student autonomy and initiative.
- Use raw data and primary sources along with manipulation, interaction, and physical materials.
- Use cognitive terminology such as "classify," "analyze," "predict," and "create" when assigning tasks to the students.
- Allow student responses to drive lessons, shift, instructional strategies, and alter content.

- Inquire students' understanding of concepts before sharing their own understanding of these concepts.
- Encourage students to engage in a dialog both with the teacher and with one another.
- Encourage student critical thinking and inquiry by asking thoughtful, open-ended questions, and encourage students to ask questions to each other.
- Seek elaboration of student's initial response.
- Engage students in experiences that might engender contradictions to their initial hypotheses and then encourage discussion.
- Allow wait time after posing questions.
- Provide time for students to construct relationships and create metaphors.
- Nurture students' natural curiosity through frequent use of the learning cycle models.

Constructivist learning allows students to take responsibility for their own learning and establish connections between ideas and thus to analyze, evaluate, and defend their ideas (Brooks and Brooks 1999).

Jonassen (1999) describes *constructivist learning environment* (CLE) as having eight characteristics: *active/manipulative, constructive, collaborative, conversational, reflective, contextualized, complex, and intentional.* Construction of knowledge by learners should have these eight qualities. In constructivist learning environment, the student as an active learner mediates and controls learning by engaging in meaningful social interaction with other students and teacher. The teacher as a moderator provides students with variety of activities that promote collaboration, interaction, reflection, experimentation, interpretation, and construction (Brooks and Brooks 1999). The challenge for educators is to design instructional strategies to actively engage learners in knowledge construction, being able to negotiate meaning, and solving complex problems (Jonassen 1999).

Educators at all levels have tried to improve their instructional practices through experimenting with constructivist learning principles. This is because constructivism focuses on how people learn and it suggests that learning occurs through active engagement in problem solving, and not simply from taking in information, replicating the information. The challenge in teaching is to create experiences that engage students in learning activities and support their own explanation, evaluation, and communication about their experiences. The teachers' understanding of the approach is limited to their personal experiences. Therefore, teachers should gain a proper understanding of constructivist philosophy and approaches in order to create effective instructional activities that are reflective of constructivist orientation.

Cross-References

▶ Active Learning
▶ Bruner, Jerame (1915–)
▶ Constructive Learning
▶ Dewey, John (1858–1952)
▶ Piaget, Jean (1896–1980)
▶ Piaget's Learning Theory
▶ Project-Based Learning
▶ Social Construction of Learning
▶ Social Learning Theories
▶ Vygotsky's Philosophy of Learning

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Constructivist Learning Environments

▶ Open Instruction and Learning

Constructivist Learning Principles

▶ Cybernetic Principles of Learning

Constructivist Learning Theory

Constructivist learning theory takes on several forms – individual, social, cognitive, postmodern – but all emphasize that learners construct knowledge using their own activities, and that they interpret concepts and principles in terms of the schemata that they have already developed. The verbs used in constructive alignment (above) are the "construction tools" that students use to meet the learning outcomes intended.

Contemplation

▶ Mindfulness and Meditation

Contemplative Science

▶ Mindfulness and Meditation

Content Area Literacy

▶ Content-Area Learning

Content-Addressable Memory

▶ Associative Memory and Learning

Content-Area Learning

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Synonyms

Adolescent Literacy; Content Area Literacy; Disciplinary Literacy

Definition

Content area learning is closely associated with the academic skills and instructional pedagogies needed to succeed within various core academic courses. Each content area has its own traditions, knowledge base, and pedagogies, including strategies for teaching and learning. Content area learning is typically driven and defined by the unique learning traditions of the four major specialty areas taught in secondary schools (i.e., social studies, mathematics, science, English Language Arts); although content area learning can also refer to learning that takes place in other courses (e.g., art history, business-related courses). Furthermore, content area teachers play a substantial role in shaping learning goals and instructional pedagogies within their courses via individually constructed understandings of the discipline's knowledge and learning traditions. Content area specialists in secondary (middle and high) schools typically demonstrate proficiency in their area through completion of a full degree or other closely related coursework. Several nations maintain the tradition of content area teachers completing an adjoining degree in teaching, which leads to national or local professional licensure.

Within each content area, there is voluminous information to transfer to students; teachers typically organize content within units of study guided by national or local standards and other curricular guidelines. A common understanding of content area learning is that each discipline's academic demands revolve around students' cognitive and academic capacity (e.g., reading comprehension, writing skills) to efficiently navigate voluminous background knowledge and literacy demands. Rich background knowledge helps facilitate student constructions of conceptual knowledge within a particular discipline; however, this cognitive construction process is often enabled or restricted by students' literacy skills. Students need strong literacy skills to successfully interact with the substantial demands generated by academic coursework, but simultaneously need strong literacy skills to demonstrate understanding and proficiency on assessments and other course requirements.

Embedded within the cognitive construction of content area material is (a) a requirement to master significant quantities of vocabulary terms, including complex concepts through a combination of reading and in-class instruction; (b) the need for students to develop and use metacognitive strategies for interacting with the discipline's content; and (c) the teacher's roles in providing explicit instruction that structures readiness to process, comprehend, and critique discipline-specific texts. Furthermore, as students progress within their respective academic programs, content area learning demands, especially those related to literacy, are augmented in significant quantities (Carnegie Council on Advancing Adolescent Literacy 2010). In summary, content area learning is a multifaceted, generative process shaped by the knowledge construction traditions unique to each content area, but is largely dependent on learners' basic literacy and higher-order thinking skills and processes (Kamil et al. 2008).

Theoretical Background

Foundational Literacy Skills. The foundation for success in content area learning is strong basic literacy skills. To succeed in content-specific courses, especially at the secondary level, a strong base of literacy skills, including comprehension (and its component parts), writing, and capacity to participate in discourse, is required (Kamil et al. 2008). The demands of content area courses, especially at the secondary level, frequently include substantial demands of discipline-specific texts in terms of reading levels and overall accessibility of document(s). Policymakers, researchers, practitioners, and other stakeholders have brought significant attention to the issue of literacy learning within the content areas across the past 30 years (Carnegie Council for Advancing Adolescent Literacy 2010). Despite this attention, effective interventions for promoting content area learning for all subpopulations have not been widespread. Thus, for many practitioners and teacher preparation programs, the emphasis for content area teachers revolves around the content and methods for teaching, while readiness to promote literacy instruction is marginalized (Moje 2007). This area is currently receiving substantial attention in the professional literature, and will continue to be a source of new research and innovation in the future.

Commonalities Across Content Area Learning. There are several characteristics of content area learning that remain constant despite preexisting differences in subject matter. The first hallmark of content area learning is the use of texts. Textbooks are a mainstay in secondary-level content courses, and contain significant quantities of vocabulary terms and concepts, and many are written with the assumption that readers possess vast background knowledge about the corresponding content area (Kamil et al. 2008). The mixture of significant quantities of new vocabulary terms and "newness" of content without existing cognitive schemas to activate during learning can hinder the comprehension of all students, but especially those with reading or other learning challenges.

Content area courses employ discipline-specific texts as well as primary source documents (e.g., journal entries, laboratory notes, letters, and policy documents). Primary source documents often contain wide disparities in terms of text structure, purpose, use of jargon, and levels of reading difficulty. In short, these documents, while rich in terms of building students' conceptual understanding of persons, events, and processes, can be very difficult to read with the efficiency and effectiveness needed for success in classrooms. Content area teachers need to provide students with explicit instruction in order to successfully engage challenging discipline-specific texts and related documents. Promoting and nurturing student metacognition is a critical element of content area learning that must be carefully addressed by teachers.

Another commonality across the content areas is the quantity of information that is transmitted from the teacher (and text and other materials) to students. Content area courses are built from and organized around standards derived from national and/or local education agencies. In the current age of accountability, the demands for content coverage have been augmented, while available instructional time has often not kept pace. This has resulted in what is sometimes called a "pedagogy of telling" which results in teachers being compelled to cover a wide breadth of material by way of sacrificing depth of understanding. For many students, including those with learning challenges, the pedagogy of telling is a mismatch for their learning needs and preferences, and frequently results in academic struggles and failures. A critical area of research in the field is the design and validation of instructional methods for addressing the compounding demands of state and local standards and curricula while not ignoring best pedagogological practices within each respective discipline area (Moje 2007).

Teacher Preparation. Shulman (1987) pedagogical content knowledge (PCK) is a well-known construct for organizing and understanding how content area teachers make sense of content and select/design appropriate methods for teaching students. Methods for organizing this content to efficiently and effectively convey content to students (pedagogy) differ from content area to content area. For teacher educators and practitioners, understanding how PCK informs teaching in the respective content areas is essential. That said, students' basic literacy skills are essential for proficient content area learning; hence, teachers have the dual responsibility of promoting literacy learning in the service of enabling advanced content mastery (Kamil et al. 2008).

Teacher preparation programs for content specialists feature coursework on discipline-specific teaching methods, but frequently are limited in terms of disciplinary literacy pedagogy (DLP) (Moje 2007). Moje's construct of DLP is an expansion of Shulman's PCK in that it reflects the need to specifically highlight and implement discipline-specific knowledge creation traditions from the respective content areas. Highlighting and explicitly teaching students the epistemological practices of the discipline is a substantial departure from many traditional approaches to content area learning. In addition, a DLP framework focuses on infusing specific literacy instruction into teaching, so that students develop capacity within the respective content areas to meaningfully interact with course texts. This epistemological approach is essential for understanding content area learning, as the capacity to understand the respective content area traditions and construction methods holds the key for higher-order thinking and learning on the part of students. That said, publicizing the discipline's respective epistemologies and translating those traditions into structured lessons for novice learners is an extraordinarily complex undertaking for many practitioners, and constitutes an area of significant need within the field of content area learning in terms of future research and innovation (Moje 2007).

Given the unique demands of each content area, teachers must make decisions about how to deliver their content in the most efficient and effective manner. In social studies courses, for example, Weinberg's (1991) framework for knowledge construction, (a) sourcing, (b) contextualization, and (c) corroboration, helps teachers explicitly teach students to think and act as historians do, which promotes deeper engagement with content. In order to participate in the active discourse of content it is necessary for students to possess adequate background knowledge, along with sufficient literacy skills to engage complex text-based documents or materials. In science courses, students are often taught to participate in active inquiry activities, which require significant know-how on the part of students that has been transmitted from their teachers.

Shulman's PCK and Moje's DLP frameworks help inform the work of content area teachers by specifying and promoting the norms and practices of experts in the respective fields. These norms and practices guide orchestration of hands-on learning made possible through underlying background knowledge and literacy tools needed to promote active and independent student learning. This constructivist approach contrasts significantly from traditional "stand and deliver" and pedagogy of telling methods that rely on passive learning on the part of students.

Important Scientific Research and Open Questions

Research in the field of content area learning can be characterized as the study of methods for helping teachers organize and deconstruct content (graphic organizers, vocabulary instruction) in order to help students access subject matter. Research that is needed in this area includes furthering understanding of how discipline experts can capture the metacognition involved in knowledge construction and critique that translates into instructional materials relevant for novice learners. In addition, significant attention in the professional literature has been dedicated to strategy instruction. Students can become cognitively active when they are explicitly taught how to learn and are given authentic opportunities to engage in the learning activities of experts in the respective disciplines while receiving ongoing feedback from teachers. Further research is needed in order to create teacher preparatory programs and practices that lead to the preparation of content area teachers to implement a disciplinary literacy framework in their classroom.

Research in strategy instruction as it relates to content area learning has focused on cognitive and metacognitive processes that learners must employ in order to master subject matter. Cognitive strategies (cognitive processes) are constructive interaction with texts, both written and digital, and include activities such as asking questions to interrogate texts, summarizing, activating prior knowledge, and organizing and engaging prior knowledge with newly learned information. A learning strategy is a person's approach to learning and using information. Students use learning strategies (metacognitive processes) to help understand information and solve problems. Some students, including many with learning disabilities, who do not know or use learning strategies are characterized as passive learners and ultimately struggle to succeed in rigorous content area coursework. Learning strategy instruction focuses on making students active learners by teaching them how to learn and how to use what they have learned to solve problems and be successful. The use of learning strategies by content area specialists allows teachers to directly embed instruction in a specific strategy through direct explanation, modeling, and required application in relation to content assignments. By teaching students strategies that are directly relevant to the demands of their courses, instructional emphasis is shifted from learning course content to acquiring the necessary cognitive processes to master the content.

An open question is the debate in the professional literature and in classrooms between the use of discipline-specific versus discipline-general teaching and learning strategies. Many existing content area–learning strategies are designed specifically to be appropriate for use in any content classroom. Empirical research for each has also provided evidence that discipline-generic strategies are effective for promoting content area learning and/or comprehension. There is a growing movement in the field of content area learning toward discipline-specific teaching. Learning strategies help students meet the widely discrepant learning demands of the respective content areas. An example is Weinberg's sourcing, contextualization, and corroboration framework for learning in history courses. More research is needed to address this open question.

Cross-References

► Aligning the Curriculum to Promote Learning
► Curriculum and Learning
► Literacy and Learning

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Content-Extending Reasoning

► Inferential Learning and Reasoning

Context and Semantic Sensitivity in Learning

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Synonyms

Context awareness; Contextual cueing; Resource sensitivity

Definition

The concept of *context sensitivity* refers to people's ability to recognize key stimuli in their environment and to use them to create subjective plausibility of the given task or situation. This corresponds with a constructivist perspective which considers human learning as an active process of knowledge construction that is dependent to a large extent on the learner's ability to strategically manage and organize all available information resources. Besides the information already stored in memory, information presented by the external environment is especially relevant.

Semantic sensitivity is a core concept not only in cognitive psychology and linguistics but also an important requirement for modern information and communication systems where context sensitivity of applications refers to the adaptivity to the situations in which a system needs to act. This enables more efficient and robust functioning in dynamic environments.

Theoretical Background

A basic assumption of constructivist approaches of learning is that learners respond sensitively to characteristics of the environment, "such as the availability of specific information at a given moment, the duration of that availability, the way the information is structured" (and presented), "and the ease with which it can be searched" (Kozma 1991, p. 180). However, this seems dependent on the learning strategies which students use in a more or less consistent manner. Entwistle (1981), for example, assumes that some learners are more consistent in their use of strategies while others behave more opportunistically or with more sensitivity to the requirements of their immediate situation. This argumentation corresponds, to a large extent, with the concept of a biological sensitivity to context as discussed in the area of psychopathology where biological reactivity to environmental stressors is widely discussed (see, e.g., Boyce and Ellis 2005). Furthermore, what Kozma says also corresponds with the idea of *contextual cueing* within the realm of cognitive psychology, where powerful and sophisticated selection mechanisms exist to spontaneously focus on aspects of a complex scene that are of significant relevance for information processing. For example, in complex visual search tasks, the global context may direct attention toward specific elements involved in the scene. This contextual guidance of visual attention reflects context sensitivity to meaningful regularities and covariances between objects within a scene (cf. Treisman and Gelade 1980). In accordance with schema-theoretical approaches of information processing, it has been argued (e.g., Chun and Jiang 1998) that relevant contextual knowledge is mainly acquired through implicit learning processes which occur without intention or awareness. Incidentally acquired contextual knowledge forms a highly robust, instance-based, *implicit memory* for context and constitutes the fundamental basis of contextual cueing as a form of schema-based automaticity. Similarly, in cognitive psychology context sensitivity has been discussed with regard to speech behavior (see, e.g., the context-sensitive associate theory of Wickelgren 1969) and word processing (Schvanefeldt and McDonald 1981); and in the area of machine learning context-sensitive learning methods for text categorization are comparable (e.g., Cohen and Singer 1999).

In contrast with schema-based argumentations, researchers in the field of mental models argue that context sensitivity occurs consciously and intentionally. Among others, Anzai and Yokoyama (1984) assume that learners encode information on a problem in a mental model as soon as they begin working on it in order to gain a basic understanding of the situation and its demands. This initial experiential model can – and the learner is generally aware of this – be false or insufficient for accurately representing the subject domain in question. However, it is *semantically sensitive* toward key stimuli in the learning environment and can thus be transformed into a new model through accurate processing and interpretation of these key stimuli. The results of the experimental study of Anzai and Yokoyama (1984) as well as those of other studies (e.g., Ifenthaler and Seel 2005; Seel and Dinter 1995) indicate the following characteristics of contextual semantic sensitivity in the learning-dependent progression of mental models:

- If the learner's initial mental model is strongly dependent on previous knowledge *from experience* rather than on acknowledged principles (for instance of physics) and if specific key stimuli from the learning environment capture the learner's attention, the initial experiential model is semantically sensitive toward these key stimuli and can be changed into a more correct model.
- Semantic sensitivity requires for the key stimuli to be related to the knowledge on which the initial model is based. Key stimuli which capture the learner's attention but are not related to the knowledge on which the "experiential model" is based are ineffective for changing this mental model.
- Which key stimuli in the environment are taken into account for the further development of a model depends primarily on the learner's domain-specific knowledge. The mental model created at the beginning of a problem-solving process is only sensitive toward key stimuli in the environment if the learners are able to recognize the principles

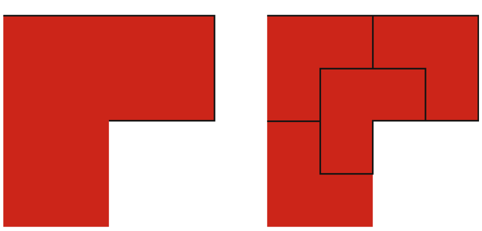
which their knowledge indicates to being relevant for mastering the given situation.

We can summarize that context and semantic sensitivity is widely accepted in various disciplines which are concerned with learning and information processing. Not only cognitive and educational psychology operates with this theoretical term but also linguistics, machine learning, and artificial learning research.

Important Scientific Research and Open Questions

Context sensitivity is fundamental to intelligent behavior. It is the context of the learners that determines which stimuli will be perceived, how interpretations are placed on incoming information, and how the learner responds to the stimuli. By paying attention to the context, an intelligent agent can spontaneously select appropriate responses to stimuli, especially of unanticipated events.

From an educational perspective, an excellent example for illustrating the relevance of context sensitivity for learning is an experimental study of Dreistadt in 1969 (Dreistadt 1969). In this study, adults had to solve two well-defined problems: In the first problem, the subjects had to separate the area of a farm into four parts of equal size and shape (see Fig. 1), and in the other problem they had to plant 20 trees in five straight rows of four trees each. For the experimental condition, Dreistadt provided pictures of various objects in the experimental room which supplied analogues to the given problems and indicated an idea for a solution. The first experiment provided the subjects with a map of the USA on which Texas and several flight paths were highlighted, a diagram with curves, and a clock on a dresser half covered by a radio (see Fig. 2).



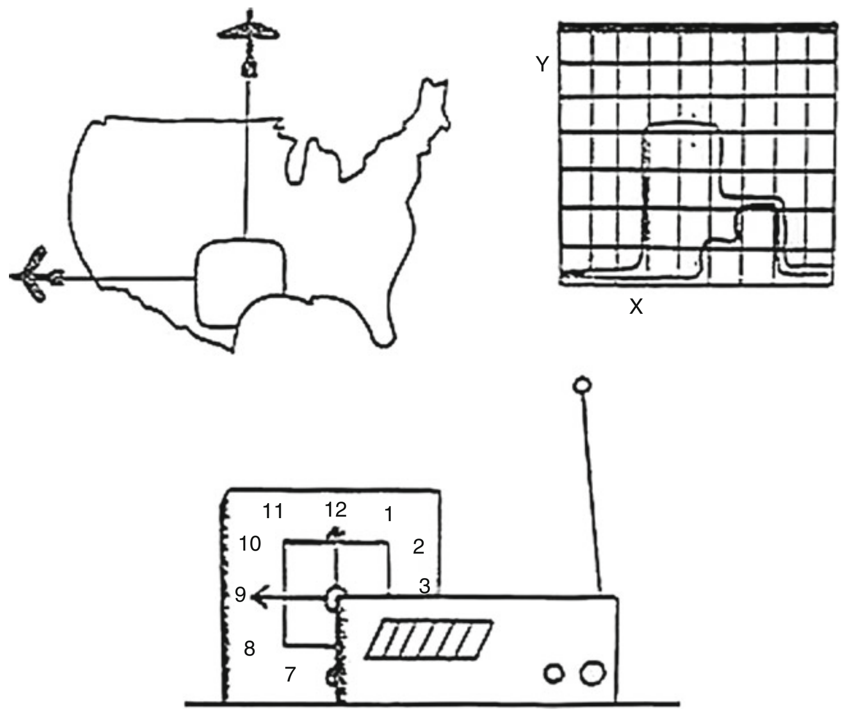
Context and Semantic Sensitivity in Learning. Fig. 1 The farm problem in Dreistadt's (1969) study on the use of analogies

The experimental condition for the second problem was designed in the same way.

The results of both experiments demonstrate the effectiveness of the analogues on display in the experimental room and thus also the context sensitivity of the learners. However, the learners' context sensitivity was only effective when they were given enough time to solve the problems.

Similarly, some research on mental models focused on the effects of semantic sensitivity on learning and problem solving. A prominent example has been provided by Anzai and Yokoyama (1984) who distinguish between the stage of initial *model construction* and the subsequent process of *model development* which is dependent on the learner's semantic sensitivity toward relevant key stimuli in the learning environment. The starting point of their study was the observation that many students have only fragmentary knowledge of physics. Although they acquire a good deal of formal knowledge in school, they are unable to apply this knowledge to new physics problems. Rather, they tend to devote their attention to, and to let themselves be distracted by, surface attributes of the problems and end up forming naive internal representations on the basis of these attributes. However, as Anzai and Yokoyama could show that students sensitively adjusted their mental models to particular information provided by the learning environment. This observation could be replicated in experimental studies done by Seel and Dinter (1995) and Ifenthaler and Seel (2005).

Alternatively to this research on mental models, various schema-theoretical approaches demonstrate also the effectiveness of context sensitivity, for instance, in visual processing as well as verbal processing. Actually, many researchers have used concepts such as "context" or "typicality" in order to explain the influence of knowledge structures on processing visual and verbal stimuli (see, e.g., Antes et al. 1981; Schvanefeldt and McDonald 1981; Treiman, Kessler and Bick 2002). When we view a visual scene, we are able to determine rapidly and effortlessly the scene's constituent objects, spatial relations, and to what semantic class the scene belongs. This corresponds largely with the *schema hypothesis*, according to which a visual scene is rapidly identified as a member of a semantic category, and contextually sensitive predictions are then used for subsequent object identification (Henderson 1992).



Context and Semantic Sensitivity in Learning. Fig. 2 The provided analogies for solving the farm problem (Dreistadt 1969)

According to this hypothesis, schemas function as a framework which promotes context-bound understanding and coherence when we process visual information. At the same time, schemas regulate the attention we devote to information depending on whether it is related to a schema or not. Everyday experiences and observations by psychologists indicate that information which is atypical for a schema attracts more attention and is thus more likely to be retained.

Context sensitivity does not only play an important role in psychological research on visual and verbal processing but rather also in the field of machine learning and Artificial Intelligence where schema-based approaches of context-sensitive reasoning are popular since the 1990s (see, e.g., Cohen and Singer 1999; Turner 1994; Turney 1996).

Schema-based approaches of context sensitivity operate basically with a top-down mechanism in successful recognition as discussed in recent neuropsychological models and research findings (e.g., Fenske et al. 2006). Actually, there is sufficient evidence for top-down facilitation of recognition that is triggered by early information about an object, as well as by contextual associations between an object and other objects with which it typically appears. In addition to object-based facilitation, a context-based mechanism is proposed to trigger top-down facilitation through contextual associations between objects in scenes. Fenske et al. point out that object- and context-bound top-down processes operate together in promoting efficient recognition by framing early information about a visual scene within the constraints provided by a lifetime of experience with contextual associations.

Cross-References

► Anticipatory Schema(s)
► Schema(s)
► Schema-Based Reasoning
► Visual Perception Learning
► Word Learning

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Context Awareness

► Context and Semantic Sensitivity in Learning

Context Conditioning

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Synonyms

Contextual conditioning; Pavlovian context conditioning

Definition

Context conditioning is the process in which contextual information becomes associated with another stimulus. Mention classical conditioning or Pavlovian conditioning to any former student of an introductory psychology class, and it may evoke images of dogs salivating to a conditioned stimulus (CS). This is because Pavlov's seminal experiments establishing classical conditioning paired a CS with food as the unconditioned stimulus (US). Initially during classical conditioning, a US produces an unconditioned response (UR), for example salivation; with repeated pairings of a CS with the US, however, the CS will evoke a conditioned response (CR) that is often, but not necessarily, similar to the UR. Over the years, numerous experiments have used various stimuli as a CS or US. For example, classical fear conditioning commonly employs a discrete tone as the CS and a mild shock as the US. Nonetheless, it has become clear that in addition to discrete stimuli, such as a tone, environmental stimuli, such as the context in which the conditioning takes place, can serve as a CS. This ability of the context to serve as CS provides a mechanism in which contextual information can exert strong control over behavioral responses.

Theoretical Background

Contextual stimuli are different from discrete stimuli such as a tone in that contextual stimuli are composite stimuli consisting of multiple individual stimuli (or elements) that together form a whole. For example, if an individual becomes sick after eating a meal at a restaurant, they might develop a conditioned aversion to the food they ate. This aversion to the particular type of food would be a discrete association between the food and the illness. However, returning to the restaurant in the absence of the offensive food may also be sufficient to evoke nausea. This would be because the context of the restaurant has become associated with the illness. As stated, in context conditioning, the individual stimuli that compose the context are bound together as a gestalt such that an individual stimulus from the environment may not be sufficient to evoke a response, but when the contextual stimuli are presented as a whole, a strong response is evoked.

Research examining the neural substrates of classical conditioning suggests that the classical conditioning of discrete stimuli such as a tone and the classical conditioning of contextual stimuli may involve different systems. In classical fear conditioning, lesions of the amygdala disrupt both the conditioning of a discrete stimulus and the conditioning of the training context; however, lesions of the dorsal hippocampus only disrupt context conditioning, leaving conditioning to a discrete stimulus intact. The hippocampus is involved in processing contextual and spatial stimuli and is thought to play a role in binding stimuli together. Further suggestion that context conditioning and conditioning of discrete stimuli involve separate processes comes from pharmacological studies demonstrating that a drug can selectively affect one type of conditioning without affecting the other. For example, nicotine administration enhances contextual fear conditioning but not fear conditioning using a discrete auditory stimulus as the CS (Kenney and Gould 2008). If context conditioning and conditioning with a discrete CS involved the same processes, then they should be similarly affected by pharmacological manipulations or by inactivation of brain regions.

Just as there are multiple types of classical conditioning, there are multiple types of context conditioning. One distinction is whether the context is the primary CS or a secondary CS. Using classical fear conditioning again as an example, when a discrete auditory CS is paired with a mild shock US, the context is a secondary CS. The context conditioning in this case would be background context conditioning (Odling-Smee 1975). However, if no discrete CS is paired with the US, the context becomes the primary CS; this is called foreground context conditioning. The distinction between foreground and background context conditioning is an important one because these two types of context conditioning may involve different processes. Background context conditioning may require more attention or vigilance in order to form a strong context association because the discrete CS may be in competition with the context for cognitive resources. In support of the idea that background and foreground conditioning involve different processes, inhibition of protein synthesis immediately after training disrupted foreground but not background contextual fear conditioning (Stiedl et al. 1999). Because foreground and background context conditioning may involve different processes, experimental variables may not have the same effects on each type of conditioning. This fact should be considered when designing and interpreting experiments.

Other forms of context conditioning exist in addition to contextual fear conditioning. Conditioned place aversion is a type of context conditioning in which subjects are exposed to different contexts that are separated by an opaque Plexiglas wall. One context is repeatedly paired with a control substance such as saline and the other side is repeated paired with a potentially noxious stimulus such as an aversive dose of a drug. After multiple trials, the Plexiglas divider is removed and the time subjects spend in each context is measured. If the subjects have learned to associate the noxious stimulus with the context in which it was administered, they should spend less time in that context. Just as a context can be associated with aversive stimuli, context conditioning can occur with appetitive stimuli. One example of this is conditioned place preference. The training of conditioned place preference is similar to the training previously described for conditioned place aversion except that instead of pairing a noxious stimulus, an appetitive or rewarding stimulus is paired with one context. If the subjects form an association between the context and that stimulus, they should spend more time in that context at testing. The paradigm is often used to examine how drugs of abuse become associated with contextual information and the processes that support this type of learning.

Another context association that can occur with drugs of abuse is context conditioned tolerance. With repeated administration of a drug, the same dose of the drug may come to elicit less of a response; this is known as tolerance. When a drug is repeatedly administered in the same context, the context can become associated with the drug administration and this context-specific association can lead to the expression of tolerance. However, because the context is controlling the expression of tolerance, administration of the same dose in a novel context can result in an overdose. For example, in a study that examined conditioned tolerance, rats were injected with doses of heroin that escalated over time; injections occurred in one of two contexts and the paring of injection condition with context remained stable throughout the experiment. Rats were then given a test dose that was nearly twice as high as the last dose of heroin administered. Rats given the test dose of heroin in the environment in which heroin was previously administered were less likely to show signs of overdose than rats given the same dose in an environment that was heroin naïve (Siegel et al. 1982). In addition to the context being able to elicit tolerance, contextual stimuli can also elicit cravings. Environments associated with self-administration will evoke drug-seeking behaviors in rodents and reports of drug craving in humans. This ability of the context to control the expression of tolerance and cravings has serious implications for understanding and treating addiction. As just one example, treating a patient for substance abuse in a clinic and then returning them to the environment where they consumed the drugs may greatly increase the likelihood of relapse.

Drugs such as the heroin discussed in previous paragraph have perceptible interoceptive effects. These perceptible effects can serve as an internal contextual stimulus much like the exteroceptive cues that compose the room where the addict takes drug, or the chamber where experiments are conducted. Like exteroceptive context stimuli, the internal context induced by a drug can acquire control of approach or avoidance-related conditioned responses when the drug state is paired with an appetitive or aversive stimulus, respectively (Bevins and Murray 2011). As an example, rats can receive daily nicotine sessions intermixed with daily saline sessions. On nicotine sessions, sucrose is available intermittently; no sucrose is available on saline days. The internal context induced by the nicotine comes to control an anticipatory approach and search in the area where sucrose had been previously given. Research in this area has indicated that the internal context is specific to the neurobiological process underlying the drug. Thus, drugs within and across pharmacological classes (e.g., stimulant versus hallucinogen) do not substitute their control of the conditioned response unless they share a common effect in the nervous system. Unfortunately, there is very little research in this area with humans and it potential import. The limited research with nonhuman animals suggests that it could be quite important in such areas as drug addiction and eating disorders.

Important Scientific Research and Open Questions

One important issue for understanding context conditioning is clarifying whether context conditioning is one learning process where the context becomes associated with a stimulus or two different learning processes where the context is learned as one process and the representation of the context is then associated with a US. In contextual fear conditioning, the context and the US are presented during the same trial, which makes it difficult to determine if learning a context is different from context conditioning. This issue has been clarified through a series of experiments that demonstrates that context learning and context conditioning can occur as separate processes. If a rodent is put into a conditioning chamber, immediately administered the unconditioned stimulus, and then removed; the rodent does not show robust context conditioning, though conditioning can occur and changes in experimental design can change this outcome. However, if the previous experiment is repeated except this time the naïve subject is also allowed to passively explore the training context on the day before the immediate conditioning, context conditioning results. This demonstrates that for context conditioning to occur, the context must be first learned and then entered into an association with the unconditioned and suggests that the context learning and the context conditioning may be separate processes (Fanselow 2000).

Contextual associations play an important role in several types of mental illness. One example in anxiety disorders includes posttraumatic stress disorder. Contextual stimuli can become associated with a stressful or anxiogenic event. Reexposure to these contextual stimuli can result in reexperiencing stress and anxiety. This becomes problematic if the repeated exposure does not lead to a decrease or extinction of the stress and anxiety responses. In addition, further complications can arise if the contextual stimuli begin to generalize to other contexts, resulting in generalized expression of anxiety. Another example already discussed is the effects of contextual stimuli on drug addiction. Contextual stimuli can contribute to tolerance and also cravings for drugs. Therefore, understanding the processes and situations in which contextual associations can generalize across contexts, the factors that contribute to or prevent the extinction of contextual associations, and the factors that allow contextual associations to have a strong influence on behavior may facilitate the development of better treatments for these and other disorders.

Cross-References

▶ Associative Learning
▶ Biological and Evolutionary Constraints of Learning
▶ Conditioning
▶ Context Fear Learning
▶ Drug Conditioning
▶ Evolution of Learning
▶ Extinction Learning, Reconsolidation and the Internal Reinforcement Hypotheses
▶ Neuropsychology of Learning
▶ Pavlov, Ivan P. (1849–1936)
▶ Pavlovian Conditioning
▶ Place Preference Learning

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Context Fear Learning

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Synonyms

Contextual fear conditioning

Definition

A form of Pavlovian conditioning where static environmental cues become associated with an aversive event and subsequently come to elicit a conditional fear response.

Theoretical Background

Context fear learning is a form of Pavlovian fear conditioning where the static, background contextual cues that define an experimental apparatus become associated with an aversive event and subsequently come to elicit a fear response. Context specifically refers to the particular arrangement of visual, auditory, tactile, and olfactory cues that define the experimental apparatus (the terms context and experimental apparatus or conditioning chamber are often used interchangeably). Together, these stimuli constitute the contextual conditional stimulus (CS) that becomes associated with the aversive event, or unconditional stimulus (US). The learning of this association subsequently drives a conditional response (CR) of fear when the contextual CS is encountered again. Fear is a defensive motivational system that evolved to optimize survival in threatening situations. It involves a constellation of behavioral and physiological responses that prepare the organism for rapid expenditure of energy, such as increased autonomic arousal, and activates species-specific defensive reactions (SSDRs). SSDRs are highly varied throughout the animal kingdom; however, the most commonly measured SSDR in context fear learning experiments involving rodents is that of freezing. Freezing is defined as complete immobility except that necessitated by breathing. In the rodent, it evolved to prevent detection by predators and to prevent predatory attack once the animal has been detected.

Context fear learning is believed to be a two-stage process. First, through active exploration of the experimental apparatus, the animal must integrate the multimodal stimuli into a unified "contextual representation" that can be used as a CS. Second, this contextual representation is then associated with the aversive US. The context-shock association then subsequently drives the fear CR. A number of phenomena in contextual fear conditioning have led to this view. Most important among these is the immediate shock deficit. If the aversive US is presented immediately after the subject is placed in the context it will acquire no contextual fear, and it thus exhibits the immediate shock deficit. Extensive experimentation has demonstrated that this deficit occurs because the formation of contextual representation has not yet occurred prior to the immediate shock and therefore there is no CS to associate the shock with. Pre-exposure to the conditioning chamber prior to the immediate shock rescues the immediate shock deficit. This pre-exposure rescue indicates that if the subject has already formed the contextual representation it can retrieve this representation prior to the immediate shock and thereby form the context-shock association. The length of time between placement in the conditioning chamber and presentation of the shock is referred to as the "placement to shock interval" or PSI. Short PSIs produce little to no conditioning, as just described. As the PSI is increased the level of conditioning increases, up to approximately 3 min when the level of conditioning becomes asymptotic. This placement to shock interval function indicates that the formation of the contextual representation occurs very rapidly, but is clearly not instantaneous. It requires integration of multi-modal sensory experience over time.

Important Scientific Research and Open Questions

A major area of current research is focused on determining the underlying neural mechanisms of context fear learning. The current view is that formation of the contextual CS occurs in the hippocampus, a region that is critical in many forms of learning and memory. It receives highly processed multi-modal sensory information from the lateral entorhinal cortex and precise spatial information from the medial entorhinal cortex. It is believed to further process and integrate this information via its three-layered laminar structure to form a multi-modal spatial representation, or cognitive map, of the environment. It is this cognitive map that serves as the contextual representation in context fear conditioning. The site of the context-shock association is believed to be in the amygdala where hippocampal inputs and shock-related information converge. Strengthening of the hippocampal-amygdala synapses via Hebbian long-term potentiation allows subsequent activation of these inputs to drive amygdala activity. Amygdala activation by the contextual CS then activates downstream structures, such as the peri-aquedectual gray (PAG), which coordinate the fear response. Thus, when comparing context fear learning with learning fear of a simple discrete cue such as a sound, the hippocampus is involved in context but not cued fear. However, the amygdala is equally important for both types of fear.

There are a number of important caveats to this view. The first is that context fear learning can readily occur in the absence of the hippocampus as long as more than one shock is presented during training. Thus, animals with lesions or pharmacological inactivation of the hippocampus prior to training with two or more shocks can acquire normal levels of contextual fear. Lesions after training or pharmacological inactivation prior to testing, however, consistently produce context fear deficits, even when multiple shocks are used. This discrepancy between pre- versus post-training manipulations has been interpreted in the following way: When hippocampal function is compromised during training, alternate structures are able to compensate and generate a contextual representation that is sufficient to support conditioning. Post-training lesions are more effective because normally the hippocampus actively inhibits and/or outcompetes these alternate structures. Therefore when training occurs with an intact hippocampus, the alternate structures are not recruited. In addition, these alternate structures are less efficient, which is why more training is required in the absence of the hippocampus. Furthermore, they are less accurate, resulting in inappropriate fear responses to other contexts that were not paired with shock. The exact site of these alternate structures is still a matter of debate; however, the slower learning rate and reduced specificity are consistent with theoretical predictions of learning in cortical structures.

Another caveat is that context fear becomes less dependent on the hippocampus as time elapses between training and testing. The general term for this phenomenon is "temporally graded retrograde amnesia" that occurs after hippocampal lesions or pharmacological inactivation. If hippocampal function is disrupted immediately after training this results in severe impairments in contextual fear. If hippocampal function is disrupted weeks after training, however, contextual fear is intact. This indicates that context fear becomes increasingly independent of the hippocampus over time. Information that is initially stored only in the hippocampus is thought to be transferred to extra-hippocampal structures over time, via a process referred to as systems consolidation. The underlying mechanisms of this process are not well understood; however, there is compelling evidence to suggest that prefrontal cortical regions play a critical role.

Cross-References

▶ Fear Conditioning in Animals and Humans
▶ Linking Fear Learning to Memory Consolidation
▶ Pavlovian Conditioning
▶ The Role of Attention in Pavlovian Conditioning

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Context of Learning

▶ Deutero-learning

Context-Based Learning

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Synonyms

Object-based learning

Definition

Context-based learning is a pedagogical methodology that, in all its disparate forms, centers on the belief that both the social *context* of the learning environment and the real, concrete *context* of knowing are pivotal to the acquisition and processing of knowledge. The approach is based on the firm conviction that learning is a social activity that is badly served by most classroom situations due to an inherent misrepresentation of how the mind acquires, processes, and produces knowledge. Learning is a communal activity centered on the interactions between persons with substantial interests and standard classroom structures that do not respond to this may well inhibit the success of learning.

Theoretical Background

The German philosopher G. W. F. Hegel succinctly critiqued theoretical approaches to questions of practical philosophy in his subtle comment about the Owl of Minerva flying only at dusk. The comment asserts that in areas of human discipline and practical activity (and education is a human activity), theory can only be a descriptive practice that arises when the trial and error and nitty-gritty of actual practical engagement with the world and people has become a stable institution. Only when such activities and conventions have progressed to an effective level are general principles and rules of conduct, in short *theory*, distilled out of everyday performances and practices. Context-based learning is perhaps only just entering into the self-conscious phase whereby thinkers reflect on the theory that can best capture an overtly practical engagement with the learning environment. The approach is still, in many ways, an immanent response to the day in day out process of learning and transmitting knowledge, whereby new techniques have been developed bottom-up rather than inspired and determined by preexisting theoretical commitments. And nowhere is such a pragmatic approach more appropriate than in a pedagogical methodology that seeks to integrate the interests of the would-be knower with the body of knowledge before him or her.

Of course, theoretical precedents have been sought in the educational literature, and two thinkers above all others seem to stand out: John Dewey, the American pragmatist, and Lev Vygotsky, the Russian psychologist. From the former, context-based learning derives an overtly pragmatic commitment: learning is an activity bound up with human interests. Just as the standard of truth and knowledge in Dewey's deeper philosophical theory is their utility, a statement is true if it is useful, so must learning prepare the subject for social engagement. In response to his theoretical commitments, Dewey believed that education ought to be dominated by real-life tasks and challenges and that theory and facts were to be learned through activity, rather than the standard model of a passive student receiving knowledge from an expert or superior. The latter thinker, Vygotsky, asserted that culture and the learner's immediate environment determine both how he or she thinks, that is, the processes of reasoning, and also the content of his or her thinking, that is, the elements of knowledge that are combined and used in the thinking process. One's success in learning is dependent upon the environment of learning and the activity is best facilitated through a process of problem solving in collaboration with peers, relations, or teachers. Intellectual development depends greatly on the social situation of learning and how interactions with teachers, relations, and peers around the learner occur. So, the *context* in which learning is *based* is a dual axis: on the one hand, the context is the social situation of learning whereby knowledge is acquired, processed, and produced through collaboration and use rather than direct dissemination; on the other hand, the context must be an engagement with a real-life task whereby knowledge interfaces with an actual, empirical reality. Both axes instigate a move away from the hierarchical model of passive-learning in the traditional lecture hall or classroom situation.

However, as indicated, it is the actual practice of context-based learning that, for the most part, reveals its commitments and implicit assumptions. The method redefines the roles of both learner and teacher: the former is to be actively involved in the learning process and the latter is to facilitate the learners' taking possession of the knowledge for him or herself. The learning process is not about rote learning of facts, but is interest governed in the sense that the learner perceives that there is something at stake in the learning rather than the mere propensity to pass an examination or gain credit. Learning is no longer seen as something happening to one, but an activity in which one is engaged. Consequently, the teacher becomes a facilitator or a supervisor of tyro researchers; he or she is no longer a dispenser of facts and theories, but an organizer of a social community of equal learners.

As the learner becomes the center of their own educational experience situated within a communal group, so he or she reflects upon the first axis of the context (the social environment), the object (the intersection of the knowledge with empirical reality), and the experience of learning. The advantage is obvious: through learning, the leaner is also *learning to learn* and progresses from a dependent student to an independent subject. The second axis of the context concerns the engagement with real-life learning challenges. These activities would ideally involve both intellectual and *physical* activity: the movement of the students, the seeking out of data, the measuring of objects, and so on. The learning context must be both a concrete reality and the site of an investment of abstract ideas and epistemological mores. So, one approach would be to invest academic knowledge of philosophy, physics, literature, and so on into a real context such as health care, art galleries, the music industry, political events, and so on, reflecting the interests of the learners themselves. A second approach would be to frame the pursuit of academic knowledge in terms of real-life challenges: the objective of making river water safe to drink (chemistry) or the understanding of why public consensus is so outraged when cadaver's organs are used without consent (philosophy). In both approaches, it is obvious that the epistemological base of the discipline is broadened (in the chemistry example, there must be an explicit discussion of why we would want safe water and where the technology would be useful) and that the acquisition of knowledge crosses disciplines (in the philosophy example, data on the medical use of organs would have to be compiled).

The process of learning should involve distinct phases. One, the learner begins with empirical engagement with the site or interaction of the knowledge that relies on facts and theories already belonging to the learner as well as knowledge shared with peers and the encounter with new knowledge in situ. Two, the learner then conceptualizes that reality in terms of concepts and theories is drawn from one or more academic disciplines. The knowledge acquired from a traditional discipline is perceived as useful to the completion of a task or in the satisfaction of the learner's self-directed interest. Three, the concepts and theories of the discipline are applied or used and thus engage reality and a concrete problem or object, so that the student sees and commands them in action. The learner takes possession of the knowledge in order to satisfy an interest. Four, the results and conclusions acquired and generated are disseminated in a variety of ways, determined by appropriateness: presentations, reports, theses, web pages, and so on. The approach encourages higher-order thinking alongside the passive acquisition of discipline-based knowledge and involves the learner in the social construction of knowledge that interfaces with a concrete reality.

The advantages of the approach are that the learning environment facilitates the internalization of knowledge and facts because they are connected to the reality of learners' lived experience. Learners are involved in the production of the knowledge in a tyro researcher role whereby a hands-on experience makes learning into a *doing* and not just a *happening*. Furthermore, learners are motivated to acquire the knowledge and see it as valuable because it solves a specific problem or engages a distinct reality. The motivation to engage in learning is interest rather than punitively driven. As a pedagogical method, it implicitly builds upon the knowledge that learners already possess and so increases confidence and independence through active involvement and social collaboration.

Important Scientific Research and Open Questions

Much of the research into context-based learning is rather appropriately an active engagement with new pedagogical techniques in specific disciplines (Anthony et al. 1998; Hansman 2001; Rose 2009). The majority of this empirical research is concerned with the effectiveness of imparting skills and relating academic knowledge to real-life challenges. In these studies, there is an attempt to compare the acquisition of knowledge concepts through traditional means and through context-based approaches. The hypothesis that underpins much of the research is that if a learner can understand why they are learning what they are learning, it will somehow be of significance to them and hence retained. The empirical case needs to show that this is more than a mere truism and the theoretical work has to articulate a framework that explains why this is the case.

There are, however, also some theoretical assumptions that deserve more attention. Most obviously, the reduction of epistemology to simple pragmatism whereby discipline-specific knowledge is only of value if it can be utilized or applied to tasks and social integration seems to prioritize skill learning over facts. Moreover, context-based learning ought to perhaps be conditional and not a universal theory. It may perhaps be more suited to specific disciplines and the balance between student-led and facilitator-governed learning will differ from discipline to discipline and perhaps also from learner to learner. A core dissemination of knowledge is required at the dependent stage and should not be discounted: independence develops from dependence and the use of context-based approaches should be attentive to these considerations. Empirical investigations are required to measure the effectiveness of the technique and to discern the correct balance between the dependence and independence at the various stages of an education.

Cross-References

► Bottom-Up and Top-Down Learning
► Collaborative Learning
► Dewey, John
► Interests and Learning
► Learner-Centered Teaching
► Personalized Learning
► Problem-Based Learning
► Project-Based Learning

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Contextual / Context Stimuli

Stimuli in the background whenever learning and remembering occur. These stimuli can be external (e.g., room cues) or internal (e.g., drug or emotional states).

Contextual Conditioning

► Context Conditioning

Contextual Control

► Effects of Physical Context Change and Perceptual Learning on Generalization

Contextual Cueing

► Context and Semantic Sensitivity in Learning
► Statistical Learning in Perception

Contextual Fear Conditioning

► Context Fear Learning

Contiguity

Contiguity is a fundamental precondition of association. It refers to the co-occurrence between two or more inputs or outputs in time or space.

Contingencies of Reinforcement

► Schedules of Reinforcement

Contingency

► Contingency in Learning

Contingency in Learning

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Synonyms

Assignment of credit; Association; Contingency; Correlation; Dependence; Prediction; Retrodiction

Definitions

Contingency: the extent to which knowledge of one event reduces uncertainty about another. *Prediction*: the extent to which knowledge of one event's occurrence enables one to anticipate whether and/or when another event will occur. *Assignment of credit*: determining to which past event an outcome event should be attributed (retrodiction). *Association*: perceived contingency. *Instrumental conditioning*: a learning protocol in which a desired or undesired is contingent on an action of the subject (or agent). *Pavlovian conditioning:* a learning protocol in which the contingency between two events is varied. *Entropy*: the measure of amount of uncertainty, aka the amount of information available in a probability distribution. *Mutual information:* the sum of the entropies of the marginal distributions minus the entropy of their joint distribution. *Uncertainty coefficient*: the percent reduction in uncertainty about whether and/or when a predicted event will occur that is produced by the occurrence of a predictor event: a broadly useable measure of contingency or association.

Theoretical Background

The concept of contingency plays a central role in the analysis of commonly studied learning paradigms and also in research on human judgments of dependence, contingency, and causality. Despite its conceptual importance, there is surprisingly little psychological literature focusing on the following question: What is the proper definition or measure of contingency?

In Instrumental/Operant Conditioning

The concept of contingency is important in the study of instrumental conditioning, because the reinforcing event only reinforces the instrumental response if it is contingent on that response. In the operant conditioning literature, the concept has often been treated as unproblematic, perhaps because the experimenter specified the contingencies that were taken to be of interest. However, implicit in many treatments of reinforcement – and explicit in discussions of the role of delay of reinforcement – is the assumption that what really matters is not contingency per se but rather the close *temporal pairing* of response and reinforcement. This makes the question of the role of contingency in instrumental conditioning the same as the question of its role in Pavlovian conditioning. The challenge in both cases is to specify what constitutes "close."

As the study of reinforcement learning from a computational perspective has become a significant focus of research in computer science and cognitive neuroscience, there has been a greater realization that it was not obvious which aspects of a sequence of actions should be regarded as the aspects on which the feedback-providing outcome was contingent. How to determine this is the assignment of credit problem. It is the contingency problem seen from the other end. It can be reformulated as: What aspect or aspects of an action sequence is an outcome contingent on? One wants a measure of contingency or dependency that is mathematically well grounded and lends itself to the apportionment of contingency or dependency among possible predictors.

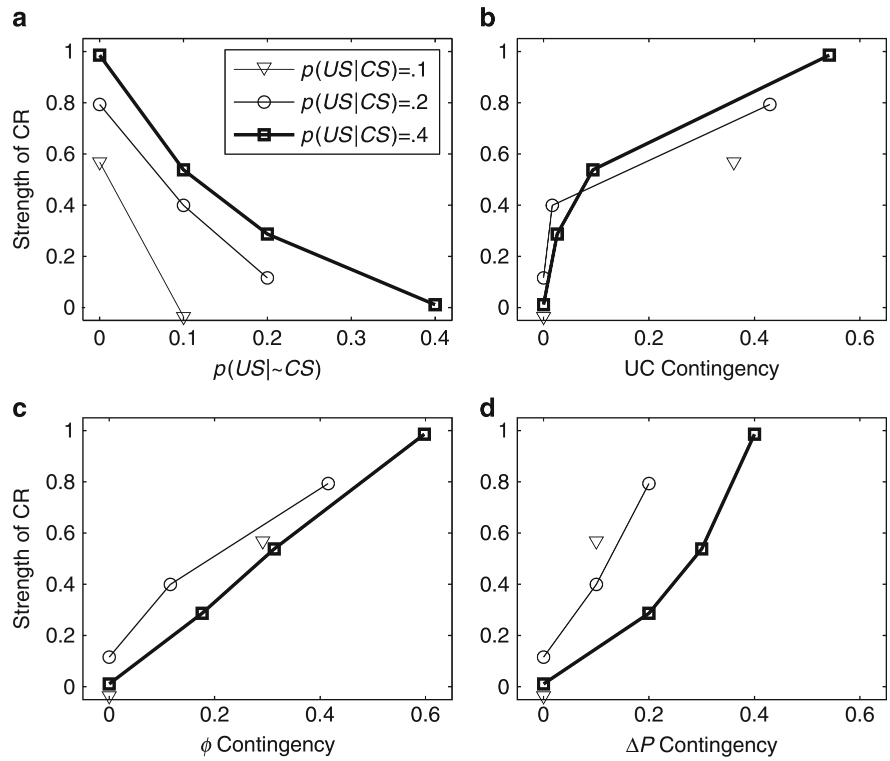
In Pavlovian/Classical Conditioning

The concept of contingency became important in the study of Pavlovian conditioning in the late 1960s when a series of experiments from different laboratories called into question the assumption that the temporal pairing was what drove the formation of an association between two stimuli or events (hereafter called the CS and US, with the CS being the predictor and the US the predicted event or stimulus). Rescorla (1968) posed the question whether it was the temporal pairing of CS and US or the CS–US contingency that led to the emergence of a conditioned response (a response to the CS that anticipates the US). He fixed the number of co-occurrences (temporal pairings) of the CS and US and varied the contingency by varying the frequency of the US during intervals when the CS was absent. When there were no the US in the absence of the CS, a strong conditioned response was seen on the post-conditioning test trials, even when $p(US|CS)$, the probability of the US given the CS, was as low as 0.1. Regardless of the value of $p(US|CS)$, as the frequency of the US in the absence of the CS increased, the strength of the conditioned response on test trials diminished (see Fig. 1). When $p(US|\sim CS) = p(US|CS)$, that is, when the contingency was eliminated, there was no conditioned response. Thus, it is predictive (and retrodictive) power or contingency rather than temporal pairing that drives conditioning. That is also the implication of the phenomena of *blocking*, *overshadowing*, and *relative validity*, which were discovered at about the same time. All of these phenomena imply that the critical aspect of a conditioning protocol is the predictive power of the CS (or of the response in instrumental conditioning), the extent to which it improves the subject's ability to anticipate when the US will occur.

Measures of Contingency

Most measures of contingency in the psychological literature derive from the numbers in a 2×2 contingency table (Table 1). Several have been used, but only two have suitable mathematical properties, such as ranging from 0 to 1 and not depending on N. Both of these are properties of the correlation coefficient, but that measure cannot be computed for dichotomous variables. For dichotomous variables in psychological experiments, Pearson's mean square coefficient of contingency

$$\phi = \sqrt{\chi^2/N} = \sqrt{\frac{(ad - bc)^2}{(a+b)(c+d)(a+c)(b+d)}}$$



Contingency in Learning. Fig. 1 (**a**). The strength of the CR on first test trial as a function of *p(US|CS)* and *p(US|∼CS)* in Rescorla's (1968) experiment on the role of CS–US contingency as against temporal pairing. Although in each of the three conditions, the temporal pairing of US and CS [hence *p(US|CS)*] was held constant, the strength of the CR declined to zero as the contingency was degraded by increasing *p(US|∼CS)*. (**b**) Performance data in **a** plotted against the uncertainty coefficient (UC) measure of contingency. (**c**) Performance data in **a** plotted against the ϕ measure of contingency. (**d**) Performance data in **a** plotted against the ΔP measure of contingency

Contingency in Learning. Table 1 2 × 2 contingency table

	#US	#∼US	Row totals
#CS:	*a*	*b*	*a*+*b*
#∼CS:	*c*	*d*	*c*+*d*
Col totals:	*a*+*c*	*b*+*d*	

is recommended by Gibbon et al. (1974), while the difference in the conditional probabilities of the US,

$$\Delta P = p(US|CS) - p(US|\sim CS) = \frac{a}{a+b} - \frac{c}{c+d}$$

has been used extensively in studies of human contingency and causality judgment (see, e.g., Allan et al. 2008).

Table-based measures are, however, problematic when applied to instrumental and Pavlovian conditioning experiments, which do not reliably have a definable trial structure (Gallistel and Gibbon 2000). This is apparent when one considers how to construct the contingency table for Rescorla's experiment. In that experiment, the CS always lasted 2 min. The interval between CSs varied around an average of 10 min. There is no doubt about how many CSs and USs there were, so the first cell (*a* in Table 1) is readily determined. All the other cells are problematic, because there is no objectively justifiable answer to the question: How many not-USs and how many not-CSs were there? The values of contingency underlying Fig. 1 were obtained by following the common practice of assuming that the intervals between CS presentations are composed of "trials" of 2-min durations each, during which a US either occurs or does not.

The number of ∼CSs is taken to be the number of such arbitrary subdivisions. The number of ∼USs is the total number of 2-min intervals, including those when the CS was present, minus the number in which a US occurred. However, the 2-min "trials" during the intervals between CSs are a fiction, as is the number of not-USs. Absent objectively defined trials, not-USs, and not-CSs have no objectively definable relative frequency, so one cannot construct a contingency table. This problem is acute in the instrumental conditioning case, because there are no trials in those protocols.

A second problem with measures based on a contingency table, and with the correlation coefficients as well, is that they take no account of time. The contingencies of ordinary experience are defined over time, and the temporal intervals between the events are centrally relevant to the psychological perception of contingency and causality. The importance of "close" temporal pairing – of response and reinforcer, or of CS and US – has always been stressed in the conditioning literature. However, attempts to specify what constitutes "close" have never succeeded. Clearly, a psychologically useful measure of contingency must take time into account.

A measure that does this is the uncertainty coefficient, also known as the entropy coefficient. It is the percent reduction in uncertainty about when (or whether) a predicted event (US) will occur gained from knowledge of the times at which (or trials on which) the predictor event (CS) occurred:

$$UC = I(CS; US)/H(US). \qquad (1)$$

$I(CS; US)$ is the mutual information between CS and US. $H(US)$ is the entropy of the US distribution. It is also called the amount of "available" or "source" information. It is the information-theoretic measure of the uncertainty regarding when and/or whether a US will occur. In the case of atemporal dichotomous variables, where there are objectively definable trials, hence objective probabilities for the failure of a US to occur,

$$H(US) = \sum p_i \ln(1/p_i) = p(US)\ln(1/p(US)) + p(\sim US)\ln(1/p(\sim US)). \qquad (2)$$

The $\ln(1/p_i)$ is the amount of information provided by the occurrence of the *i*th event in the set of possible events over which a probability distribution is defined (e.g., the US and ∼US events). It is also called the surprisal. Intuitively, the less probable the event, the more unexpected or surprising it is, the more we are informed by its occurrence – but, by the same token, the less often we are so informed. As may be seen from Eq. 2, the entropy, *H*, of a distribution is simply the average surprisal, that is, the amount of information provided by each of the possible events weighted by its relative frequency.

Entropy is the technical term for the amount of uncertainty in a probability distribution, which is the same as the amount of information available from that distribution, because information reduces uncertainty. The mutual information between two events with observed or experimenter-defined probability distributions is:

$$I(CS; US) = H(CS) + H(US) - H(CS, US),$$

where $H(US, CS)$ is the entropy of the joint CS–US distribution. In the case where a contingency table can be constructed, the US distribution is given by the normalized column totals, that is, the column totals in Table 1 divided by *N*; the CS distribution is given by the normalized row totals; and the joint distribution is given by the normalized cell values (a/N, b/N, c/N, d/N). For each distribution, the entropy is: $H = \sum p_i \ln(1/p_i)$.

The UC measure applies to temporal uncertainty as well (Balsam and Gallistel 2009). If USs (or reinforcers) occur at random times, then the uncertainty regarding when the next US will occur is the entropy of an exponential distribution, which depends only on the average US–US interval (the reciprocal of the base rate). This entropy is the basal uncertainty about when the next US will occur. It is the amount of available information. If a CS always precedes a US and always tells us exactly when to expect the US, then there is no residual *objective* uncertainty about when the next US will occur once the CS has occurred. In that case, the UC is 1, that is, the CS reduces the uncertainty about when the next US will occur by 100%. However, humans and other common laboratory animals can only estimate the duration of an elapsing interval with about +/− 15% accuracy. To be useful, the CS must precede the US by some interval. Our residual uncertainty about when exactly to expect the US is then determined by our imprecision in estimating when the remembered CS–US interval has elapsed. Thus, the effective percent reduction in our uncertainty depends on the ratio between the basal interevent interval (the average US–US interval) and the CS–US interval (the delay of reinforcement). The greater this ratio is, the greater the percent reduction in our uncertainty. Thus, this way of measuring contingency explains why "close" temporal pairing is important. However, "close" is relative (to the basal interevent interval), not absolute; there is no critical interval that defines whether two events are or are not temporally paired.

Important Scientific Research and Open Questions

The UC measure of contingency provides a rationale for the two ideas in the famous Rescorla–Wagner model of association formation: $\Delta V = \alpha(\lambda - \sum V)$, where V is associative strength. This formula rests on two assumptions: (1) The sum across all the associations from differents CS to one US cannot exceed some limit, which is represented by the asymptote parameter, λ. (2) Associative strengths are additive; their sum is subtracted from λ in determining the amount by which any associative strength is to be incremented, ΔV. The entropy of the US distribution, which determines the amount of available information, puts an upper limit on the amount of information that all predictors combined can provide. Moreover, the entropies of independent events (and independent conditional entropies) are additive. An open question is how far this can take us in understanding the objective basis for the phenomena of cue competition (blocking, overshadowing, relative validity) – see Balsam and Gallistel (2009).

Another open question is whether and how the brain can compute the uncertainties on which the UC measure of contingency depends.

Cross-References

- ► Association Learning
- ► Associationism
- ► Bayesian Learning
- ► Communication Theory
- ► Connectionist Theories of Learning
- ► Formal Learning Theory
- ► Human Contingency Learning
- ► Law of Effect
- ► Reinforcement Learning
- ► Temporal Learning in Humans and Other Animals

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Contingency Learning

- ► Associative Learning
- ► Causal Learning
- ► Causal Learning and Illusions of Control

Continuing Education and Training

- ► Lifelong and Worklife Learning

Continuing Professional Development

- ► Professional Learning and Development

Continuous Assessment

- ► Formative Assessment and Improving Learning

Continuous Improvement

- ► Learning Cycles

Contradictions in Expansive Learning

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Synonyms

Expansive learning; Expansive learning and its conditio sine qua non

Definition

The term "expansive learning" designates a mode of learning which enhances the quality of one's life by increasing power and control over one's own societal living conditions. Thus, the concept addresses individual or collective learning processes with the goal of extending agency, action possibilities, and self-determination – as well as, more generally, free human development. "Contradictions in expansive learning" refer to two different matters: Firstly, societal contradictions which obstruct development are subjected to collective learning to resolve them. Expansive learning is then seen as a method (similar to action research) to improve cooperative activities and their organizational structures. However, secondly, contradictions may occur as a specific effect of power relations that make conditions of expansive learning into a means of adapting and subordinating people to the demands of "flexibilized" labor markets and "precarious" living conditions.

Theoretical Background

The term "expansive learning" was introduced to the sciences of learning over two related theoretical frameworks: (1) the Finnish version of Activity Theory and (2) the German–Scandinavian version of Critical Psychology. Definitions vary in each framework, as does the interpretation of contradictions.

1. Engeström (1987) focuses on expansive learning as a collective mastery of societal problems achieved by resolving systemic obstructions or organizational limits of "activity systems." His idea of grasping learning in social rather than purely individual terms is partly based on Klaus Holzkamp's utopian concept of "generalized agency" (*verallgemeinerte Handlungsfähigkeit*) (Holzkamp 1983). Accordingly, the mastery of societal problems is understood as part of a fundamental process of sociohistorical development, which is seen as being driven by the contradictory nature of human activities under capitalist societal relations.
2. By contrast, Klaus Holzkamp (1993) focuses on learning mainly as individual action. In general and irrespective of any particular influence of capitalist relations or other forms of subordination, he sees learning as directed toward overcoming feelings of powerlessness, dependence, fear, or despair and thus improving one's quality of life. However, given the disciplinary power regime of institutionalized education (or schooling) – including techniques of selection, individualization, punishment, and normalization (cf. Foucault 1977) – this potential is structurally restrained or even foreclosed. Learning often turns out to be rather mechanical with little sustainability because learners tend to adopt a passive attitude: Efforts are made to avert negative consequences (such as bad grades), to pass an exam, or merely to please a teacher. Subjective reasons for embracing the endeavor and the risks that come along with learning remain "defensive" rather than "expansive" (Holzkamp 1993). Regarding this problem, the concept of expansive learning is an analytical rather than a descriptive or normative one. Analyses of the structural obstructions of learning thus make the contradictory effects of schooling visible.

Against the background of both approaches, Langemeyer (2005) investigates policies and approaches of vocational education that aim at ensuring "employability." In this context, the traditional understanding of education as instructional pedagogy is increasingly replaced by learner-centered approaches (such as work-based or workplace learning, self-regulated or self-organized learning, and competence development). Different from schooling, these approaches allow more autonomy and individuality within the actual learning process and demand greater personal (learner) responsibility for progress and success. Yet since they emerged within the context of the flexibilization of working conditions, the transformation of the welfare state toward a "lean state," the recurrence of precarious living conditions, and the rise of a new ("high-tech") mode of production, they pose new questions with respect to the theorization of contradictions. Similar to Foucault's governmentality approach, Langemeyer maintains that, under these conditions, self-responsibility and self-management are not only aspects of self-determination, but paradoxically also a means of adaptation and subordination. Due to this shift from "disciplinary power" toward "technologies of the self," self-dependent forms of learning are marked by *new* contradictions, or more precisely, by power relations that act increasingly "through subjectivity." Instead of encouraging and enhancing collective learning, these contradictions enforce tendencies of individualization and thereby impair the potential of (expansive) learning.

Important Scientific Research and Open Questions

Contradictions as both the motive and the object of collective learning activities at various workplaces (e.g., in the Finnish health care sector) were investigated empirically by Engeström and collaborators at the University of Helsinki (Engeström 2001). These studies are centered on the idea of "developmental work research" which harnesses workers' active involvement in improving their cooperative work activities and their working conditions (cf. Toikka et al. 1985; Engeström 2005). Developed on the basis of psychological thought (Vygotsky, Leont'ev, and others), this approach is not only highly regarded internationally, it has also exerted broad influence on various other disciplines, such as the sociology of work and organizations, human resources management, communication sciences and the media, software design, and science and technology studies (cf. Roth and Lee 2007, p. 188). However, despite this wide recognition, several critiques have emerged concerning Engeström's theoretical framework as well as his methodological basis (e.g., Toomela 2008; Langemeyer 2006; Langemeyer and Roth 2006; Avis 2007). Among other objections, Engeström's conceptualization of transformation and change was ultimately seen as "conservative" (Avis 2007), as adjustable to capitalist needs of revolutionizing the mode of production, and thus as incompatible with Vygotsky's engagement for transformative social practice and dialectical thinking (cf. Stetsenko 2008) Furthermore, these critics rejected Engeström's adaptation of functionalist and systemic views on human activity, which largely neglects the level of subject/subjectivity and therefore ignores the kind of power effects which Foucault, for example, addressed as "subjectivation" (*assujettisement*).

By contrast, Holzkamp's "subject-science" of learning discusses "internalized constraints" and the "expropriation of expansive learning," for instance when one's own interests and those of others are so "intertwined" that "power is not acting on the subjects from the outside but through them, through their subjectivities" (Holzkamp 1993, p. 523, my translation). However, this problem is insufficiently reflected in Holzkamp's use of the analytical categories "defensive learning" and "expansive learning." In particular, the concept of "defensive learning" is tailor-made for the problems of schooling (e.g., the resistance of pupils against education), whereas "expansive learning" seems to be only its positive counterpart, but still conceived within the same paradigm. Holzkamp exemplifies his vision of a self-determined education with some of his own individual experiences – of learning something "for its own sake." Against this background, expansive learning becomes associated with a practice free from restrictions, disturbances, or contradictions. Yet this interpretation would be misleading with regard to challenges of self-responsibility under flexibilized and precarious working conditions.

An empirical study on workplace learning of IT specialists by Langemeyer shows a way of combining insights from Engeström's and Holzkamp's approaches in view of a new societal problem. To explain the new type of contradictions, Langemeyer (2005) argues that motivation to embrace the challenges of self-responsibility depends on how a person makes sense of them. The subjective meaning ascribed to one's own living conditions is analyzed as a reflection of one's vital needs and interests and situated knowledge (cf. Holzkamp 1993). Moreover, subjectivity is seen as immersed in social relations of everyday life, shaped by social processes of interpretation and negotiation, and thus as susceptible to narrow-mindedness and ideologies. Consequently, the capacity or competence for self-regulated learning and self-management, Langemeyer argues, does not "reside" as a stable character trait "*inside*" a person. She thus contradicts approaches which assume that this competence would exist prior to specific learning or work activities. Instead, she explains that it develops with raising awareness of the matters of work or life in general, how they emerged, why they are at stake, and in what ways they can be changed. This awareness is seen as a result of collective learning, which is envisaged, following Engeström, as both a theoretical and practical intervention. In other words, the desired competence coevolves with the learning or work activity.

The new type of contradictions is then illuminated as follows: On the one hand, the desired effects of self-responsibility essentially depend on the growth of learners' personal sense and self-will (*Eigen-Sinn*), that is, on a specific kind of personality development. On the other hand, this personal sense and self-will is often pervaded by work relations in which resources are limited and objectives are shortsighted or even contradictory. This kind of contradiction can be studied best by focusing on learning trajectories rather than subjective reasons to learn as Holzkamp suggests. Given, for example, the subordination of workplace learning to work routines or management structures, learning trajectories are often constrained by inadequate forms of participation and cooperation. Although at one moment in time, a number of aspects of expansive learning may be prevailing (motivation for learning, engagement for problem-solving, and self-responsibility may be high at the beginning of a course or a training program), in the long run they may be gradually overshadowed by a discrepancy between the learner's desired and actual performance and between planned achievements and shortcomings. Holzkamp's focus on subjective reasons and on learning as individual action proves to be too narrow to address this problem, while Engeström's notion of contradiction as systemic dysfunction and as the driving force of development is too broad. By contrast, Langemeyer's notion of "contradictions in expansive learning" aims at theorizing the dynamics of expansive learning. Her empirical approach consists of a three-dimensional analysis of forms of cooperation, modes of participation, and changing aspects of a person's situatedness. It understands power relations that prevent the learning or working subjects from exerting influence and gaining the power to act as the crucial point of societal contradictions. In so doing, Langemeyer does not expect contradictions to be the driving force for development or an obstruction for learning per se. She reasons that any engagement for changing and enhancing activities must be seen as a contradictory practice itself. The study of contradictions in expansive learning is therefore a constant challenge "to generate – each time anew – critical perspectives on these societal practices in which we participate, and on our own social-individual basis to act and to reflect on the problems and conflicts to be resolved" (Langemeyer and Roth 2006, p. 40).

Cross-References

► Activity Theories of Learning
► Apprenticeship Learning in Production Schools
► Collaborative Learning and Critical Thinking
► Collective Learning
► Communities of Practice
► Cultural-Historical Theory of Development
► Independent Learning
► Learning Activity
► Lifelong and Worklife Learning
► Self-determination of Learning
► Self-organized Learning
► Self-regulated Learning
► Sociocultural Research on Learning
► Socio-technological Change of Learning Conditions
► Trajectories of Participation; Temporality and Learning
► Workplace Learning

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Contrast

► Simultaneous Discrimination Learning in Animals

Control Processes

Control processes in the Atkinson–Shiffrin model are strategies for managing learning such as deciding how to encode the material (verbal repetition, semantic associations, visual images) and subsequently retrieve it from memory. For example, attempting to recall the names of all 50 states in the USA could be organized either by alphabetical order or by geographical regions.

Controlled Information Processing

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Synonyms

Effortful information processing

Definition

Controlled information processing is a mental process that requires attention and cognitive capacity and has to be initiated by the subject. It is considered to be limited, slow, serial, effortful, and used for unskilled tasks. It is initiated intentionally and shows benefit from practice. Performance will change from controlled to automatic after extensive training under the precisely the same conditions. Automatic processing is considered to be the opposite process to controlled processing.

Theoretical Background

During the 1950s, the cognitive psychology focused on the capacity limits of human information processing (HIP), such as how the brain treats incoming information (stimuli). The British psychologist Broadbent introduced a significant model of information processing in 1958 and was one of the first to draw a distinction between automatic and controlled processes. Further work by Posner and Snyder (1975) implicated the automatic process to be an unconscious and unintentional process, whereas the controlled process requires conscious intention. This view was redefined by Schneider and Shiffrin in 1977 and has since then been supported by convincing evidence and thereby kept its relevance during the decades. In the "dual-process" information processing model of Schneider and Shiffrin, a distinction between "automatic detection" and "controlled search" emphases two fundamentally different human information processing operations. According to this view, automatic processing is parallel, fast, and a result of repeated training on a task, whereas controlled processing is slow, serial, limited, and effortful. A new skill requires controlled information processing and, increasingly, as the skill is mastered, it becomes more automatically processed. For example, learning how to read is initially effortful and requires extensive cognitive capacity and gradually, reading training will change the information processing to a more automatic process. A novice reader needs more time and has more errors compared to a skilled reader. Another example is when first learning how to drive a car and becoming an experienced driver, where information processing transfers from operations which requires controlled processing to more automatic operations.

Important Scientific Research and Open Questions

Numerous behavioral studies have shown that extensive training on precisely the same task increase the speed of performance and improve response accuracy and thereby change from controlled to automatic. Various experimental paradigms have been developed in order to examine the distinction between automatic and controlled processing. The dependent variables Reaction Time/Response Time (RT) and Accuracy (AC) are often used as an indication of processes taking place, when solving a task with increasing demands on cognitive information processing. These studies have been examining information processing within different cognitive domains, such as Memory, Attention, and Executive functioning. Several neuropsychological studies have investigated automatic and controlled information processing in various patient groups, such as ADHD, learning disorders, patients with frontal lobe brain damage, Alzheimer´ Disease, Depression, etc. In cognitive neuroscience, different techniques, such as ERP (event-related potentials), fMRI (functional magnetic resonance imaging), and PET (positron emission tomography), have aimed to provide evidence for the brain localization of automatic and controlled information processing. So far, the frontal lobes have been identified as the brain region related to controlled information processing, whereas automatic information processing has been proved more difficult to localize.

Cross-References

► Automatic Information Processing
► Bottom-Up- and Top-Down Learning

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Controlled Motivation, Instrumental Motivation

► Understanding Intrinsic and Extrinsic Motivation: Age Differences and Meaningful Correlates

Convention

► Learning and Evolution of Social Norms
► Normative Reasoning and Learning

Convergent Evolution

Occurs when evolutionary pressures acting on different lineages result in (i.e., converge on) similar patterns.

Convergent Thinking

► Divergent Thinking and Learning

Convergent Thinking and Learning

Convergent thinking is a term coined by J. P. Guilford in the 1950s in the context of his research on creativity. In contrast to divergent thinking, which is considered a major constituent of creativity, convergent thinking encompasses thought processes which aim at finding the one right, best, or conventional answer to a problem. The idea of convergent thinking is based on the assumption that there is only one correct answer to a problem and that it must be found through reference to declarative knowledge. Related learning processes therefore are mainly concerned with considering available information from various sources (such as declarative knowledge) with the aim to find the correct or best solution of a problem.

It has often been criticized that school learning is strongly oriented toward convergent thinking and learning (Jones and Cooper 2006). Nevertheless, it is the best method to employ when a single correct answer exists and can be found on the basis of stored declarative knowledge. Furthermore, it is an essential precondition of logical reasoning. If appropriate declarative knowledge is retrievable then convergent thinking is quick and accurate.

With regard to learning it is noteworthy that convergent thinking is closely related to cumulative learning of knowledge, which can be easily applied in future situations involving similar types of tasks and problems to be mastered.

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Conversation

▶ Communication Theory

▶ Discourse

Conversation Analysis

Also known as CA, is a special type of discourse analysis specially designed for the study of everyday verbal and nonverbal communication. The aim of CA is to describe structure and patterns of casual conversation and of institutional talk (e.g., in school, surgery, or court). Developed in the late 1960s and early 1970s principally by the sociologist Harvey Sacks, Emanuel Schegloff, and Gail Jefferson, CA is grounded in foundational assumptions of ethnomethodology, a branch of sociology that focuses on the question of how people produce the mutually shared social order in which they live (ethnomethodology was founded by Harold Garfinkel and Erving Goffman).

Convex Relaxations

▶ Relaxations for Learning

Co-occurrence

▶ Measures of Association

Co-Ontogenic Structural Drift

A term coined by Humberto Maturana and Francisco Valera (1987) to address how living system and environment mutually specify each other. Living system and environment (which includes other living systems) change their structures over time as they interact and accommodate each other – thus, they have a co-history of change. In co-ontogenic structural drift, we either live/learn together or we part company or we die.

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Cooperation

▶ Altruistic Behavior and Cognitive Specialization in Animal Communities

▶ Multi-robot Concurrent Learning

Cooperation Scripts

▶ Collaboration Scripts

Cooperative Learning

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Synonyms

Collaborative learning; Group learning; Small group learning; Team learning

Definition

Cooperative learning is the instructional use of small groups through which students work together to maximize their own and each other's learning (Johnson et al. 1994). It is related to collaborative learning, which emphasizes that learning occurs as an effect of community (Johson and Johnson 1999). It is, however, contrasted with individualistic and competitive learning in which students work by themselves to accomplish learning goals that are not related to others, and compete with each other for grades (Johnson et al. 1998). There are three types of cooperative learning. The first type is *formal cooperative learning* which consists of students working together, for one class period or several weeks, to achieve a joint learning goals and complete tasks assigned. The second type is *informal cooperative learning* which includes students working together to achieve shared learning goals in temporary, ad-hoc groups that last from a few minutes to one class period. The third type is *cooperative base groups* that are long term, heterogeneous cooperative learning groups where members give support, encouragement, and assistance needed to accomplish the shared goal and succeed academically (Johnson et al. 1994; Johson and Johnson 1999). For an activity to be cooperative, it should have five basic elements: *positive interdependence, individual accountability, face-to-face promotive interaction, social skills, and group processing* (Johson and Johnson 1999). *Positive interdependence* means that students feel committed to one another and the success of one member is dependent on the other group mates. *Individual accountability* requires each group member to be responsible for contributing a fair share of the work within the group. *Face-to-face promotive interaction* in where students promote each other's success by sharing resources, helping, and praising each other's success. *Interpersonal and social skills* include leadership, decision making, and communication skills. Finally, *group processing* requires group members to communicate not only how well they are achieving but to coordinate their efforts (Johnson and Johnson 1999).

Theoretical Background

There are several theoretical perspectives that have guided cooperative learning. Cooperative learning is based on a variety of theories in anthropology, sociology, economics, political science, psychology, and other social sciences. In psychology, however, where cooperation has received the most intense study, three major theories have guided the research on cooperative learning: (1) social interdependence, (2) cognitive-developmental or constructivism, and (3) behavioral learning theories. The first theory, *social interdependence theory* views cooperation as resulting from positive interdependence among individuals' goals. Groups are seen as dynamic wholes in which a change in the state of any member changes the state of other members. According to Johnson et al. (1998), the basic premise of social interdependence theory is that the way social interdependence is structured determines how individuals interact, which in turn determines the individual and group outcomes. Positive interdependence (cooperation) results from promotive interaction as individuals encourage and facilitate each other's efforts to learn. In the absence of a functional interdependence (that is, individualism) there is no interaction as individuals work independently without interchange with each other. The second theory that guides cooperative learning research is *cognitive-developmental theory* that is grounded on the work of Piaget and Vygotsky. Piaget's work is based on the premise that when individuals cooperate in the environment, socio-cognitive conflict occurs that creates cognitive disequilibrium, which in turn stimulates cognitive development. Vygotsky's work is based on the premise that knowledge is social, constructed from cooperative efforts to learn, understand, and solve problems. The third theory, *behavioral learning theory* focuses on the impact of group reinforcers and rewards on learning.

Important Scientific Research and Open Questions

Many studies have shown that when correctly implemented, cooperative learning improves information acquisition and retention, higher-level thinking skills (i.e., reasoning skills), interpersonal and communication skills, and self-confidence (Johnson et al. 1998). These multiple outcomes that have been studied can be classified into three major categories: achievement, positive relationships, and psychological health. The research clearly indicates that cooperation, compared with competitive and individualistic efforts, typically results in (a) higher achievement and greater productivity, (b) more caring, supportive, and committed relationships, and (c) greater psychological health, social competence, and self-esteem (Johnson et al. 1998). Findings from a meta-analysis

(Johnson et al. 2000) supported the effectiveness of cooperative learning on students' achievement/ outcomes (e.g., grades). A total of 158 empirical studies were included in the meta-analysis. Results revealed that cooperation promotes higher achievement than do competitive (Cohen's $d = 0.82$) or individualistic efforts (Cohen's $d = 1.03$). Cooperative learning also promotes higher achievement as compared to competitive or individualistic efforts (Cohen's $d = 0.59$ and 0.91 respectively). The authors concluded that it is reasonable to hypothesize that the effective use of the cooperative learning method will likely promote learning and other achievement-related outcomes.

As another example, Felder et al. (1998) conducted a longitudinal study to examine engineering students' achievement and attitudes in a cooperative learning environment versus students' achievement and attitudes in traditionally taught classes (i.e., lecture). The authors found that students in cooperative learning outperformed students in traditional context. Students in the cooperative learning environment had higher scores and better attitudes toward instruction than did students in the traditional context. In addition to its effect on learning outcomes and attitudes, cooperative learning showed positive effects on retention, critical thinking skills (i.e., analysis and synthesis), and peer interaction. Cooperative learning caused higher students' retention rates, development of critical thinking skills, and higher peer interaction as compared to traditional lecture. Felder et al. (1998) suggested that the more cooperative learning features that instructors implement, the greater the learning improvements they can expect.

Even though there has been many experimental studies that examined the effect of cooperative learning on students' learning outcomes, some researchers have further studied the grouping effect, team composition based on achievement scores, (i.e., homogeneous versus heterogeneous) within cooperative learning environment on students outcomes. For example, Baer (2003) compared heterogeneous cooperative learning groups with homogeneous cooperative learning groups who were formed based on their first test scores. The results indicated that, overall, homogeneously grouped students significantly outperformed heterogeneously grouped students on the final exam. Particularly, high- or average-achievers benefited from homogeneous grouping while low achievers did equally well in either a homogeneous or heterogeneous group.

Although there has been a growing body of literature and empirical studies in the area of cooperative learning; many of the studies conducted looking at the impact of cooperative learning methods on achievement have methodological shortcomings and, therefore, any differences found could be the result of methodological flaws rather than the cooperative learning method (Johnson et al. 2000). In the future, researchers should concentrate on conducting highly controlled (experimental design) studies that add to the confidence with which their conclusions will be received. Future research studies need to investigate the effect of different variables in the cooperative learning process such as, group composition (heterogeneous versus homogeneous), group selection and size, structure of cooperative learning, amount of teacher intervention in the group learning process, differences in preference for cooperative learning associated with gender and ethnicity, and differences in preference and possibly effectiveness due to different learning styles or self-regulation strategies, in addition to any mediating, moderating, or interaction variables that may affect the cooperative learning process.

Cross-References

- ▶ Academic Learning
- ▶ Action-Based Learning
- ▶ Altruistic Learning
- ▶ Collaborative Knowledge Building
- ▶ Collaborative Learning and Critical Thinking
- ▶ Collaborative Learning Strategies
- ▶ Collective Learning
- ▶ Communities of Practice
- ▶ Engagement in Learning
- ▶ Interactive Learning Environments
- ▶ Knowledge Integration
- ▶ Learner-Centered Learning
- ▶ Learning in the Social Context
- ▶ Participatory Learning
- ▶ Peer influences on Learning
- ▶ Peer-Learning
- ▶ Social Learning

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Cooperative Learning Groups

► Cooperative Learning Groups and Streaming

Cooperative Learning Groups and Streaming

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Synonyms

Ability grouping; Composition of groups; Cooperative learning groups; Setting; Small groups; Tracking

Definition

Cooperative learning is a form of active learning where students work together to perform specific tasks in a small group. Streaming refers to the composition of learning groups as a collection of individuals who have regular contact and frequent interaction, mutual influence, and who work together to achieve a common set of goals. Group composition can be examined in large (i.e., between-class) and small (i.e., within-class) groups. Group composition refers to the formation of the group on the basis of some characteristic of group membership. Common grouping characteristics include ability and gender although ability grouping is the more common form.

Ability grouping involves selecting students with the intent of controlling heterogeneity within a class or small group. Two forms of between-class ability grouping are common in schools. Sometimes, students are tracked by ability across the curriculum. Alternatively, students are grouped by aptitude such that an individual can be assigned to high-ability classes for some subjects, but not for others.

Small groups may be formed with partners of common or dissimilar ability, although researchers often call for groups to be formed heterogeneously to ensure that diverse opinions and resources are reflected within the groups.

Gender grouping generally refers to the formation of entire schools by gender. Some researchers argue single-sex schooling may benefit females' academically by countering school environments that may be hostile to females. However, little empirical research has compared the effects of single-sex and coeducational schooling.

Theoretical Background

Whole Class Ability Grouping

Ability grouping proponents claim that teachers cannot adequately teach to the widely differing ability levels produced when students are grouped heterogeneously by ability. Teaching in mixed-ability classrooms forces teachers to focus attention on students at the class mean. Hence, mixed-ability classrooms are said to be too complex for the least able and lack challenge for the most able students.

Ability grouping critics are concerned that ability grouping has damaging cognitive and social emotional effects. Homogeneous ability grouping is considered to be unfair to the weakest students whose progress suffers. In classrooms where the most able students have been removed, those remaining lack effective role-models and are subject to lower teacher expectations. Some argue that ability grouping is inherently undemocratic by creating de facto segregation: Ability groups tend to reflect social class and ethnic norms, thereby perpetuating traditional class and ethnic distinctions.

Researchers have noted different teaching practices in homogeneous classrooms. Instruction for the highest performing students tends to be characterized by teaching strategies that require deep and meaningful content manipulation and negotiation. Instruction for those in lower ability groups tends to focus on memorization and the application of rules and algorithms. Schools that adopt ability grouping tend to employ the most traditional teaching methods. In the United Kingdom, performance discrepancies between high- and low-performing students were greatest in schools using whole class teaching.

Ability grouping, which is closely related to achievement in secondary education, impacts students' self-concept. Academic self-concept, which is formed through social comparison, is diminished for students in low-ability groups and is associated with negative attitudes toward future learning experiences. The extent to which ability grouping is practiced within a school further impacts academic self-concept. Self-concept is highest in schools with the least ability grouping and lowest among students attending the most highly stratified schools (Ireson and Hallam 2009).

Whole-class grouping continues in many elementary and secondary schools although little research supports the practice. Slavin examined the effects of ability grouping on achievement in elementary and secondary schools. Using an approach known as a best-evidence synthesis (which uses results from meta-analytic research and literature reviews), he reported an overall effect size of 0 indicating no benefit to the practice of between-class grouping (Slavin 1987). However, some grouping benefits were reported in elementary schools for subjects that are inherently hierarchical: Cross-grade grouping benefitted reading instruction and within-class ability grouping benefitted mathematics instruction. Slavin cautioned that when ability grouping is employed, the following guidelines should be applied:

- Grouping plans must be flexible. Students tend to remain in a group once an initial assignment has been made. To be effective, ability grouping must allow students to change groups as ability changes.
- Grouping must be specific to content. Assigning students to ability groups should be limited to the teaching of specific skills. Ability grouping should reflect different ability levels within a subject matter area rather than to a general ability measure.
- Grouping must be followed by changes in teacher behavior. Teachers must modify the pace and level of instruction when ability groups are formed.

Small Group Ability Grouping

Although many forms of small group learning exist, most fall into three categories: peer tutoring; informal groups; and cooperative learning groups. Peer tutoring occurs when a more able peer teaches or mentors a less able peer. In informal learning groups, students work together on a common task for a relatively brief time-period (ranging from a few minutes to an entire class period), but often with little structure or guidance defining how group members should collaborate. In formal learning groups, often termed cooperative learning groups, students collaborate according to some form of systematic activity or script that guides participants' behavior. For example, in Learning Together (Johnson and Johnson 1998), team members work on a common goal that is structured around five themes: positive interdependence; individual accountability; effective interaction; communication skills; and group processing.

Numerous studies have examined the effectiveness of learning in small groups. Results suggest that within k-12 schools, small group learning effectiveness increases as group structure increases. Thus, cooperative learning tends to be more effective than other forms of small group learning in k-12 schools. Even in less rigorous studies, cooperative learning is at least as effective as other forms of large and small group work and meta-analyses indicate an effect size in excess of .6. At the college level, all forms of small group learning appear to be effective in Science, Technology, Engineering, and Mathematics (STEM) classes. At the college level, small group learning is associated with improved academic achievement, persistence, and attitudes and the overall effect sizes for achievement are approximately .5 standard deviations.

Although the superiority of group versus individual learning does not appear in question, the issue of group ability composition has not been resolved. Homogeneous grouping proponents claim that high-ability students benefit from being academically stimulated and challenged by similar ability partners. Critics argue that mixed-ability grouping provides accesses to diverse opinions and resources and better prepares students for life in a diverse world. Additionally, heterogeneous grouping is said to benefit high-ability students when they explain lesson content to their less able peers, and low-ability students who receive help and explanations from more able partners. Although disagreement exists concerning the effects of ability grouping for cooperative learning, one result appears to be consistent: Low-ability students perform less well when grouped with similar ability than higher ability partners.

Gender Grouping

The issue of gender grouping has both pedagogical and political implications. To some, single-sex schooling provides females and males with educational settings in which they can thrive: Students can study in environments free from the social pressures induced by the opposite sex. Yet to others, single-sex schooling is perceived as a barrier to effective socialization.

Lee and Bryk (1986) concluded that single-sex education is particularly beneficial to female students in secondary schools. They found that single-sex schools deliver advantages to their students including increased academic achievement, enhanced attitudes and motivation, and improved academic behavior. Similar results were found in the UK, where single-sex schools were particularly beneficial to high-performing 16-year-old girls who outperformed males attending single-sex schools and were more likely to explore non-gender stereotypic subject matter. Moreover, the rate of high-performing girls attending single-sex schools was three times the rate for those attending coeducational schools (Sullivan et al. 2010).

Kinzie et al. (2007) found that women benefitted from the types and frequency of "purposeful activities" and the personal progress made in diverse educational outcomes that occur at women's colleges. Students experience higher personal expectations from faculty than do their counterparts at coeducational colleges. They interact more frequently with faculty (who tend to be more accessible) and meet faculty outside of class more frequently than do women at coeducational institutions. Similarly at women's colleges, student leadership opportunities are greater and more students enroll in traditionally male-dominated math, science, and engineering classes.

Important Scientific Research and Open Questions

According to Slavin, sufficient research has been conducted on the effects of whole class ability grouping among students through 9th grade, but research is still needed to examine ability grouping effects in grades 10–12. Research is also needed to examine changes in teaching practices under different grouping plans and the development of more reliable assessments to support accurate data measurement.

Research is needed to examine how productive learning groups can be formed among participants working at a distance. For example, although cooperative learning has been validated across cultural contexts, research is needed to understand how cross-cultural collaboration should be managed to promote effective group work.

Research is also needed to examine the design and effectiveness of computer-based tools that enhance the basic elements that make cooperation work. Many of the studies examining group composition in small groups occurred before the evolution of the Internet. Recent development of the so-called Web 2.0 technology creates new opportunities for collaboration in small groups. Researchers have become interested in whether online learning and virtual communities of practice can be fostered through collaboration. Hence, research is needed to determine whether embedded scripts, computer-tutors or pedagogical agents, or other forms of design can foster collaboration.

The composition of online groups could be reconsidered and perhaps reframed in terms of the processes underlying successful group collaboration. Since young children can be considered domain novices with relatively uniform and unspecialized domain knowledge, cooperative learning groups in schools can be considered homogenous in terms of domain knowledge. Indeed, such groups probably also bring well-established social norms (from playground and classroom interaction) to the group setting. However, for online groups, the learning environment may be heterogeneous in ways that have not been previously considered. Due to the sparse communication and other inherent potentially limiting features of the setting, it is unclear whether people working in heterogeneous ability groups can communicate productively at a distance. Similarly, other group composition findings may not transfer from face-to-face to online settings. If so, considerable research is needed to determine the optimal composition of learning groups in online settings.

The rarity of single-sex schools makes comparison with coeducational schools difficult; hence, research studies in this area often involve comparison of nonequivalent groups. For example, single-sex schools tend to be private and selective in student admission with the result that their students tend to be more motivated and from higher SES levels, thereby invalidating the comparison with coeducational schools. Single-sex schooling is often considered anacronistic, and the popularity of coeducational schooling is often viewed as a central reason for its use. Yet, the social benefits of coeducational benefits should be weighed carefully against its academic impact. In particular, research is needed to explore the nature of the high-school experience within single-sex schools.

Cross-References

▶ Ability Grouping (and Effects) on Learning
▶ Collaborative Learning
▶ Cooperative Learning
▶ Generic Architectures for Cooperative Learning Environments
▶ Group Cognition and Collaborative Learning
▶ Group Dynamics and Learning
▶ Group Learning
▶ Shared Cognition
▶ Small Group Learning

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Cooperative Learning Strategies

▶ Collaborative Learning Strategies

Coordinated Joint Engagement

▶ Joint Attention in Humans and Animals

Coping

▶ Coping with Stress
▶ Resilience and Learning

Coping Strategies

▶ Coping with Stress

Coping Style

▶ Coping with Stress

Coping with Stress

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Synonyms

Coping; Coping strategies; Coping style; Stress

Definition

Coping is usually defined as the conscious use of cognitive, affective, or behavioral efforts to effectively deal with externally imposed events and demands that the individual perceives as unpleasant or potentially harmful. To most coping theorists, the coping process consists of efforts to reduce perceived stress through a wide range of thoughts, emotions, and actions directed at both external stressors and internal demands and needs.

Coping has been categorized as both a dispositional and a situational construct. As a dispositional construct, coping may be considered a person's *style*, or disposition. As a situational construct, coping consists of the conscious use of *strategies* for the purpose of either improving one's internal resources (e.g., confidence, resourcefulness, hardiness, mental toughness) or managing external demands. Thus, coping *style*, also called dispositional or higher order coping, is defined as a person's disposition, or orientation, toward the preferred use of selected types, or categories, of coping strategies (Anshel et al. 2001). Coping style has been traditionally defined as "methods of coping that characterize the person's reactions to stress either across different situations or over time within a given situation." These coping "methods" are used consistently in dealing with stressors across time and in various situations. Coping *strategies*, on the other hand, is the situational use of a technique to reduce external demands or improve internal resources in dealing with an event perceived as stressful or unpleasant.

Theoretical Background

The process of coping with stress has a rich theoretical framework. The coping literature is replete with coping theory and models that reflect the coping process. Most of these models can be represented by the following structures and processes commonly referred to as the coping process. This section is divided into the coping process and the primary theoretical frameworks that explain coping.

The Coping Process: Appraisals and Coping Strategies

The coping process begins with an event or stimulus that is appraised as stressful. Appraisal is the person's determination whether a particular environmental encounter is relevant to his or her well-being and, if so, in what way. More specifically, Lazarus and Folkman (1984) contend that appraisal consists of the individual's evaluation of a particular encounter with the environment, reflecting the person's evaluation of the situation as relevant. They categorize appraisal as irrelevant, benign-positive, and stressful. Stress appraisals are further divided into harm–loss, threat, and challenge subcategories, a framework that has received extensive attention by researchers in the extant general and sport psychology literature. Threat appraisals are those in which the perception of danger exceeds the perception of abilities or resources to cope with the stressor. Challenge appraisals, in contrast, are those in which the perception of danger does not exceed the perception of resources or abilities to cope. Thus, because the absence of a stress appraisal begins with the athlete's perception of an event that is appraised as stressful, making non-stressful appraisals (e.g., positive, harmless) requires no coping (Anshel et al. 2001). An appraisal labeled *stressful* can reflect negative feelings, such as threat or worry, or relatively positive feelings, such as challenge or heightened arousal. Tomaka et al. correctly acknowledge that harm–loss appraisals occur *after* stressful situations abate, while threat and challenge appraisals occur *before* or in anticipation of stressful situations. Threat appraisals, therefore, are accompanied by feelings of worry that nothing will be gained from the stressful situation. Challenge appraisals, on the other hand, provide hope that there will be something gained by the situation, and envision positive incentives or avoidance of an unpleasant event.

Persons who feel inadequate or overwhelmed to deal with the stressful situation or view their coping skills as inadequate are likely to make threat appraisals. On the other hand, individuals who perceive themselves as prepared to handle the stressful event possess proper coping skills and feel confident in the outcome of the situation are more likely to make challenge appraisals. Threat appraisals are more strongly associated with negative emotional reactions than challenge appraisals (Lazarus and Folkman 1984).

Another appraisal conceptual framework is called *perceived control*, or *controllability*. Perceived control refers to the extent to which a person believes that the outcome of an event can be attributed to internal (personal) sources, external (situational/environmental) sources, or to the cause or predictability of an event. Perceived control, therefore, is the person's belief that the individual can determine one's own internal state and behavior, influence one's environment, or to bring about a desired outcome from the stressful event, either by producing desirable events or preventing undesirable events.

As the case with all types of cognitive appraisal constructs, perceived controllability influences the individual's coping response. The major determinants of coping responses are the individual's appraisal of the stressor (Anshel et al. 2001). In the general psychology literature, personal (e.g., dispositions) and situational factors (e.g., source and/or intensity of the stressor) influence the ongoing appraisal of threats and resources in responding effectively to those threats.

Coping Styles and Strategies

The next step in the coping process is that the person initiates a coping strategy, which is situational, that often, although not always, reflects the person's coping style. It is important to note that coping *strategies* reflect situational ways of dealing with stress, whereas coping *style* is dispositional and more predictable than a strategy. Thus, the person's coping style should predict the type, or category, of coping strategy the person will enact following a stressful appraisal.

Coping styles, or the coping strategies that reflect them, have been categorized different among various researchers and theorists. One popular framework is approach and avoidance (Anshel et al. 2001; Krohne 1993). *Approach coping* (styles and strategies) reflects the person's intensified intake and processing of unpleasant or threatening information. If one's safety or welfare is at stake, for instance, the person must remain vigilant toward the stressor until the situation has been resolved. *Avoidance coping*, on the other hand, reflects the person's conscious attempt at physically or mentally turning away from the stressful source. For example, because coping consumes energy and attentional resources, a person may want to be distracted by the stressor or psychologically distance oneself from the stressful source, similar to understanding the reasons the explain behavior patterns of an unpleasant person, or reducing the importance of an unpleasant situation.

A common framework for examining coping strategies more than coping styles is problem-focused and emotion-focused coping. *Problem-focused coping* concerns the individual's attempt to reduce or manage stress by directly dealing with the problem that is causing the distress, that is, an attempt to manage or control a stressful situation. Removing oneself from an actual or potential unpleasant event or peacefully confronting the source of stress by obtaining additional information are examples. *Emotion-focused coping* concerns the individual's conscious decision to deal with the stressor by regulating his or her emotions, or maintaining emotional control. Taking a deep breath and relaxing after a stressful event or discounting the importance of the stress source are examples. Both coping strategies are useful and effective, as needed, given the demands and characteristics of the situation (Lazarus and Folkman 1984).

Finally, whether the coping effort was successful – coping effectiveness – is the last segment of the coping process. Authors in the coping literature have designated *nine* outcomes of effective coping: (1) to reduce psychological distress; (2) to obtain accurate information about environmental demands; (3) maintain proper internal mechanisms (e.g., attentional focusing, proper vigilance and arousal level, rapid and accurate decision-making procedures) to process incoming information, and to know when and how to react properly to stressful events; (4) reduce or manage physiological reactions (e.g., heart rate, muscle tension) that may result in negative emotion and impair performance; (5) improve mental well-being and a positive self-image; (6) maximize the likelihood of returning to prestress activities; (7) create a stable psychological and emotional status that successfully directs energy and intentional behavior to meet external demands; (8) reduce and, if possible, eliminate harmful environmental conditions; and (9) resolve the stressful situation by producing a desirable affective or performance outcome. Taken together, there is general agreement that coping is a function of several cognitive processes that are influenced by a series of personal and situational factors. See Zeidner and Endler (1996) for a more extensive review of this literature.

Coping Theories

The *theoretical frameworks* that help explain coping include the trait/dispositional model, the contextual/situational model, and the transactional model. The *trait/dispositional model* posits that a person's use of coping strategies is stable and cross-situational; coping is a unidimensional personality variable. It is assumed, therefore, that a person's coping thoughts or actions can be predicted from the person's score on a coping inventory. Researchers have tended to not find extensive support for the trait theory of coping because the coping process has been viewed as multidimensional. While trait measures are generally inadequate in describing the complexity of the coping process, proponents of the trait model contend that personality plays an important role in an individual's persistent application of their personal coping style following stressful events, such as "the approacher" or "the avoider."

The *contextual, or situational, model* posits that coping is assessed in relation to specific stressful conditions or situations. It is assumed in this model that coping cognitions and behaviors are influenced by the relationship between the person and the environment following a particular event that is appraised as stressful. In this model, then, coping consists of changing thoughts and behaviors used by the person to manage external demands and/or internal resources (e.g., confidence, anxiety, arousal, hardiness). To many proponents of the contextual model, coping consists of managing the problem (i.e., problem-focused coping) and regulating emotions (emotion-focused coping).

The *transactional model* describes the individual and the environment in a continuous, bidirectional relationship. Transactional theory is designed to be used in reference to a specific stressful experience, rather than explaining the use of coping strategies – both problem-focused and emotion-focused – across situations. In addition, this theory refers to what a person actually thinks or does (i.e., the use of strategies), rather than what they usually do (i.e., reflecting coping style) or what they think they should do. Finally, the theory reflects general coping strategies, which apply to a variety of stressful encounters or in various stages of a single stressful encounter.

Important Scientific Research and Open Questions

The coping process is complicated and multidimensional. Each dimension of coping includes different conceptual frameworks and structures. For example, some studies have examined coping in response to chronic stress, while other studies have examined acute (situational) stress. In addition, cognitive appraisal has been conceptualized as perceived controllability or as a function of harm–loss, threat, and challenge (Lazarus and Folkman 1984; Rice 2000). The use of coping *strategies* have often been used, tested, and reported interchangeably with coping *styles*. Relatively little research has been devoted to understanding the relationship between the use of coping strategies and the effectiveness of those strategies. That is, coping effectiveness has received relatively scant attention. In addition, coping has been measured inconsistently across studies, and a person's self-report of their coping strategies has consisted primarily of recalling events that may have occurred years before, or are responding to hypothetical situations. Finally, there is a deficiency of psychometrically validated coping inventories that were constructed for the sample currently being studied. These research issues have clouded conclusions in our understanding of the coping process and the most valid means of measuring this process. More experimental new research is needed to determine the effect of coping skills training on selected cognitive and behavioral outcomes. Specific questions include the following:

1. What conceptual model of cognitive appraisal, which is a mediating variable of coping, best predicts a person's use of coping strategies?
2. To what extent do coping strategies reflect a person's coping style? Similarly, does coping style explain a person's typical use of selected types of coping strategies?
3. How can we best measure coping effectiveness? How should "effectiveness" be operationally defined in our attempts to measure the proper use of coping strategies?
4. To what extent do moderating variables (e.g., age, gender, culture, stress intensity, coping style, personality, situational factors) influence a person's use of coping strategies and the effectiveness of those strategies?
5. Which of the primary coping models most strongly describe, explain, and predict a person's coping skills?

Cross-References

► Stress and Learning
► Stress Management

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Copying

► Imitation: Definitions, Evidence, and Mechanisms
► Imitative Learning in Humans and Animals

Copying, Acquiring Knowledge Within a Group

► Imitation and Social Learning

Core Beliefs

► Maladaptive Schemas in Patients with or Without Personality Disorders

Core Constructs

► Maladaptive Schemas in Patients with or Without Personality Disorders

Core Self

► Development of Self-consciousness

Corporate Elearning

► Advanced Distributed Learning

Corpulent

► Obesity Stigma, Evolution, and Development

Corpus Callosum

The corpus callosum is the largest fiber tract in the brain. It is the thick, white band of nerves that connects the two hemispheres of the brain and allows both halves to communicate sensory, motor, and higher order information to coordinate activity.

Correlation

► Contingency in Learning

Correlational Learning

► Connectionist Theories of Learning
► Hebbian Learning

Correspondence

► Analogy/Analogies: Structure and Process
► Role of Similarity in Human Associative Learning

Correspondence Courses

► Distance Learning

Corroboration and Contextualization

► Historical Thinking

Cortico-spinal Entrainment

► Learning-Related Changes of β-Activity in Motor Areas

Cost Complexity

► Adaptive Proactive Learning with Cost-Reliability Trade-off

Cost-Noise Trade-Off

► Adaptive Proactive Learning with Cost-Reliability Trade-off

Counseling

► A Tripartite Learning Conceptualization of Psychotherapy

Counseling Outcomes

► Learning from Counseling

Counting

► Accounting and Arithmetic Competence in Animals

Couple and Family Therapy

► Application of Family Therapy on Complex Social Issues

Course of Study

► Curriculum and Learning

Courseware Learning

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Synonyms

CAI; Educational software; E-learning; ICT education

Definition

Courseware is a term that combines the words "course" with "software." It is software containing educational content, instruction, and instructional strategies. Its meaning originally was used to describe additional educational material intended as kits for teachers or trainers or as tutorials for students, usually packaged for use with a computer. Courseware learning is the process of learning through Courseware. CAI and educational software are terms that are also used to describe Courseware. CAI stands for computer assisted instruction or computer aided instruction. CAI is a program that contains instruction contents and assistance to instruction using a computer. It is difficult to distinguish between CAI and courseware. Sometimes Courseware and CAI were used as the same concepts in reference to a sort of educational software which refers to all types of software for education. Educational software is classified as instructional software, learning software, and education management software. Classified instructional software supports group learning in a classroom for teachers, and learning software supports individual learning for students. Education management software assists management of education. Some examples of the assistance that education management software provides are evaluation, educational material management, and instructor management. This education management software is called CMI (Computer Managed Instruction).

Courseware is educational software that can be categorized as instructional software or learning software. The instructor should use Courseware in accordance to its advantages and characteristics in learning. Courseware should not be overused. The important thing is that Courseware learning does not substitute; rather it should assist in traditional learning. Therefore, Courseware can be just an auxiliary or subsidiary media to support learning.

Theoretical Background

Courseware learning has been continuously changing as a result of the constant development of Courseware format, and Courseware format has changed in accordance with the development of computer environments. The main concept of the computer and educational software was the subsequent change of the Mainframe to the personal computer, CD-ROM, Internet, e-learning, Mobile learning, and Ubiquitous learning.

Courseware was operated on the mainframe computer until 1970. The PLATO (Programmed Logic for Automated Teaching Operations, 1960) project was the first developed Courseware in the University of Illinois that was based on the mainframe computer (Smith and Sherwood 1976). It then appeared on personal computers such as the Altair8000 in 1975. It made the transfer from the mainframe computer to personal computers. By the personal computer emergency, the computer can be used increasingly at home and at school, and Courseware was distributed widely and populated (Ceruzzi 2003).

When the CD-ROM appeared in 1990, the personal computer could process the large volume of data and could process multimedia data such as voice, image, and video data. Therefore, Courseware extended from text to multimedia data. Courseware supporting multimedia contents are called MBI (Multimedia Based Instruction) (Alessi and Trollip 2001). By the end of 1990, the Internet was developing rapidly and the educational software and Courseware were running based on the Internet. Courseware that is running on the Internet is called WBI (Web Based Instruction, Khan 2001). WBI supports learning to overcome time and space limitations. It provides not only the interaction between contents and learner, but provides the interaction between instructor and learner, and interaction among learners. WBI provides newly updated material and various types of information through the Internet. Due to Internet development, it made the move from off-line learning to on-line learning and finally leads to e-learning. The essential and most important part of e-learning is the quality of the e-learning content. E-learning content is the same as Courseware; therefore, the success of e-learning is highly dependent on the quality of the Courseware.

In 2000, the Internet environment was developed to support wireless networks so various mobile media such as cellular phones, ► smart phones, and PDA (Personal Digital Assistants) appeared. And the mobile media tried to include educational contents and Courseware. In the near feature, we will learn using Courseware through new devices supporting ► ubiquitous computing environments.

Courseware learning supports individual learning with consideration of the difference of individual. Courseware provides Learner initiated learning. While the instructor chooses the contents and gives a lecture to learners on a massive scale through his own intentions in classical learning, the learner can choose the contents and can study at his learning pace, at his level, and according to his interest in Courseware learning. Courseware provides self-directed, self-paced learning, and learning based on various media.

Courseware has characteristics such as interaction, individual learning, and motivation. Price (1991) mentioned the following:

1. Courseware supports individual learning and allows for self-directed learning.
2. It supports interaction and active learning. The learner can get an immediate response as a result of using Courseware.
3. It supports variety. The learner can develop an interest through the graphics, sound, dynamic animation, and various feedbacks.
4. It supports record keeping. Through the record keeping of the computer, by saving learning history and recording learning accomplishments, Courseware can make a diagnosis and provide suitable learning.

5. It supports flexibility. After evaluating the learner, we can increase or decrease learning volume.
6. It supports timeliness and responds instantly to the learner's actions. An impatient learner and those with a lack of curiosity in the subject can be captivated by instant results of Courseware.

Also, Courseware learning has the following advantages: Firstly, through simulation learning, it supports learning activities that cannot be accessed in classical learning due to time limitations, cost, and danger. Secondly, it allows the learner to repeatedly practice the things that he learns. In classical learning the teacher has limitations in giving a lecture repeatedly, but Courseware learning allows the learner to repeat lectures and practices as many times as is necessary. Thirdly, it makes learning interesting by combining the contents with games, and activities. This is especially useful for children.

However, Courseware has some disadvantages:

Firstly, it is initiated not by the instructor but by the learner. There is potential for ineffective results for learners who lack learning motivation or intention. Secondly, it is not easy to build Courseware that is assured of quality.

Courseware designers must consider general pedagogical issues such as the appropriateness of the computer, methodology, student practices, lesson length, and mastery level. Courseware design should adapt to the learner's skill and knowledge.

Important Scientific Research and Open Questions

The study of Courseware learning is classified into two parts: building effective learning Courseware, and effectively applying the Courseware in learning activities. Therefore, one is the development of effective Courseware in the computer science field, and the other is effectively using Courseware in learning as instructional methods and the instructional technology field.

The study of Courseware development is combining Courseware and ► Artificial Intelligence (AI), Wenger et al. 1987). This is called ICAI (Intelligent Computer Assisted Instruction, Kearsley 1987) or ITS (Intelligent Tutoring System, Sleeman and Brown 1982). ICAI (e.g., GUIDON) was developed to improve upon the limitations of traditional CAI. The Study of ICAI requires the system to be able to diagnose student's performance and provide the optimal student modeling process. A branch study within ICAI refers to adaptive learning system (e.g., iWeiver system) which attempts to find the most suitable learning strategy considering each learner's learning styles, learning history, and learning goals. Adaptive learning system is an implementation of ► Aptitude-treatment interaction (ATI). Most adaptive learning system studies are developed considering learning styles (e.g., Tangow system). Other studies of Courseware development are ► authoring tools, educational games and are represented in the instructional model, interaction, learning motivation, evaluation and feedback design, interface design, and screen design in Courseware.

The studies for the effective use of Courseware learning are mainly concerned with the analysis of learning results or effects in Courseware learning (Kuilk and Kuilk 1991). Courseware produces positive effects in logical learning such as mathematics and science subjects. Multimedia learning is effective by supporting multisensory learning (Heinich et al. 1996). Learning is best facilitated through a combination of complementary visual and auditory information (Mayer 1997). Multimedia learning produces positive results in foreign language learning. Also, Gleason (1981) applied educational software to general students and students in a controlled group. He reported more effectiveness in the controlled environment.

The blended learning that was integrated in on-line learning (e-learning) and off-line learning (face to face education) is one of the approaches to improving learning accomplishments.

Generally, if Courseware is properly used, Courseware can improve learning effectiveness and efficiency.

On the other hand, there are several research studies that suggest that Courseware is not meaningful and effective because of the insufficient quality of the content (Alessi and Trollip 2001).

Cross-References

► Adaptive Learning System
► Web Based Instruction

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Covariation Learning

► Human Contingency Learning

Covert Articulation

► Covert Pronunciation and Rehearsal

Covert Pronunciation and Rehearsal

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Synonyms

Articulation; Covert articulation; Covert rehearsal; Covert speech

Definition

Covert pronunciation is the act of imagining that one is speaking a particular syllable, word, phrase, or sentence. It can serve many purposes, such as helping the imaginer to learn a new word, think about a speech passage, plan a series of activities, or solve a problem. The term *covert* means without outward expression, i.e., in this instance silently, in contrast with the term *overt*, which in this instance means spoken aloud. *Rehearsal* sometimes is used to refer to the use of any mental activity to memorize a series of items; it, too, can be carried out covertly. Although this can include such processes as mental imagery or abstract thought, in the present context the term rehearsal refers only to the use of covert pronunciation for the sake of remembering.

Theoretical Background

There are various reasons why speech may be only imagined rather than spoken aloud. One may wish to avoid disturbing other people or looking crazy by talking to one's self. Yet, the need to talk to one's self even covertly (silently) very much suggests that talking to one's self serves important ends. Much of human thought itself is probably in the form of language, though it is probably not the case that all thought is in the form of language. (It can also be in the form of mental imagery, for example.)

The Russian psychologist Lev Vygotsky (1962) believed that children learn to regulate their own thoughts first by speaking to themselves or others aloud and then, typically between the ages of 3 and 7 years, learning to make that speech more internal. Young children label things, reminisce, and imagine activities with their toys and dolls or action figures, and speak these things aloud.

To the extent that covert speech is a part of ordinary thought, it is very difficult to study. That is because an experimental participant who is asked to do something like solve a problem can be "lost in thought," not having enough free attention to reflect carefully upon what he or she is covertly saying while solving the problem. In some studies of thought, people have been asked to speak aloud instead of silently but there is always the concern that an individual would alter the spoken language to impress the experimenter, compared to the ordinary covert version of speech during thought.

It is easier to study a specialized use of covert rehearsal to memorize information. Researchers have found that series of items typically can be remembered well, with a minimum of effort, if one can covertly rehearse them (Gathercole and Baddeley 1993). Among the vast amount of information stored in the human mind, it is possible to think of only a very small amount at one time (this being the part that is called the current contents of *working memory*) but often that is all the information one needs. For example, going into a grocery store you may need to remember to buy, bread, eggs, cheese, and a spatula. Covert rehearsal helps one to memorize the list or keep it in working memory for a sufficient time. It also can help in the memorization of a new word, such as a person's name. Without covert rehearsal, new information tends to fade in a matter of seconds or is quite vulnerable to interference from subsequent speech information.

Important Scientific Research and Open Questions

A convenient finding that makes it easier to study covert rehearsal is that it appears to take place at about the same speed as overt rehearsal (Landauer 1962). You can test this yourself with a stopwatch. Ask a friend to count to 20 aloud as fast as possible while articulating each of the numbers, starting when you say "go," and to knock on the desk as soon as he or she finishes the last number. Now do the same test again but ask the participant to count silently instead of aloud. Do this a few times each way. You probably will find that the amount of time taken to speak aloud or silently is remarkably similar.

It seems clear that people use covert speech as a means to retain verbal information. For example, in the 1960s and early 1970s, R. Conrad published research on peoples' immediate recall of a series of letters. Researchers have referred to this work widely and have followed up on it (e.g., Cowan et al. 1987; Gathercole and Baddeley 1993). Conrad found that even when lists were printed instead of spoken, recall of these lists was impeded most when the letters sounded similar, not when they looked similar. For example, it is relatively easy to remember the series *c, f, q, p, o, r, y* with the letters in order, and much more difficult to remember the series *b, t, v, p, c, z, d* with the letters in order, because the letters rhyme in the latter case. It is thought that when one tries to rehearse items that rhyme, they are confused with one another so that the usual benefit of rehearsal does not accrue. The poorer memory for items that sound similar is termed the *phonological similarity effect*.

Flavell et al. (1966) studied how children learn to use covert rehearsal to remember sets of pictures. They made use of the fact that when the list is difficult, children often move their lips while rehearsing; this activity might be considered partly covert (in that not much sound is being made) and partly overt (in that the lips are moving). In order to allow children to be less self-conscious, they wore a helmet and the visor was brought down, obscuring the child's vision while he or she tried to remember the pictures. The visor did not cover the mouth, however, so it was possible for the investigators to see whether the child's lips moved. The finding was that rehearsal seemed to occur in only 10% of the 5-year-old children, increasing steadily to 60% of the 7-year-olds and 85% of the 10-year-olds. This rehearsal also went along with better memory for the pictures.

Cowan et al. (1987) made use of the phonological similarity effect to examine the benefit of rehearsal in adults. Participants were to remember and then repeat series of words that sounded dissimilar (*brick, spoon, cat*, etc.) or series of words that sounded similar (*mat, bat, cat*, etc.). To be counted correct on a trial, the serial order of words in the series had to be reproduced correctly. The index of memory was the length of lists that could be correctly repeated, or *memory span*. Memory span in adults displays a strong phonological similarity effect: span for phonologically similar words is much lower than for dissimilar words. This effect is thought to occur partly because of the confusion in memory between similar words when they are *recalled*, but partly when they are *covertly rehearsed*. For example, the adult may try to remember the words by covertly rehearsing them in a cumulative manner, in order, as they are presented. Encountering *brick*, the participant rehearses *brick*; then encountering *spoon*, the participant rehearses *brick, spoon*; and so on. For lists of phonologically similar words, the order is somewhat likely to be incorrectly changed during rehearsal. When adults' ability to carry out rehearsal was suppressed by requiring that participants quietly recite the alphabet while hearing the list, both the magnitude of the phonological similarity effect and the overall level of performance (especially on lists of dissimilar words) were greatly reduced, to the point that the pattern of responding in adults with their rehearsal suppressed closely resembled what is usually found in 5-year-old children.

Although covert rehearsal is important for remembering the serial order of items, it is also important simply for remembering the items themselves. In *free recall*, unlike serial recall, the participant is free to remember the items in a list in any order he or she wishes. The recall is usually best for items at both the beginning and the end of the list. In some research, individuals have been asked to do their rehearsal aloud rather than silently and that research has indicated that the recall of items from the beginning of the list, the *primacy effect*, can be understood through rehearsal processes. Specifically, the words from the beginning of the list are rehearsed throughout the list and what matters for recall of a particular word is how recent the last encounter with the word is, either through actual presentation of the word or through covert rehearsal of it. The few items presented first are the ones most likely to be rehearsed throughout the list, bringing recall of them up to par with the few items presented last.

Despite a great deal of research, we do not really understand exactly how rehearsal operates during memory tasks. It may be that participants recite items in a repeating loop to keep their phonological representations active in memory (see Gathercole and Baddeley 1993). Another possibility, however, is that participants use covert rehearsal to form groups of items in memory. If you see the telephone number *6345789* you may mentally group it as *63-45-789* as in a rock and roll song touting that number (or more conventionally as *634–5789*). You could do that grouping by covertly rehearsing the number with mental pauses between the groups of digits.

It is difficult to know exactly what is going on when a covert mental process is taking place. This is especially true when the process extends over a relatively long period of time (e.g., a few seconds or more, as rehearsal seems to do) and is complex (e.g., changes rapidly with time, as rehearsal probably must do). Brain research can help us to learn when rehearsal is taking place but it will probably have to be accompanied by especially clever behavioral studies to help us understand exactly what is being rehearsed. All of this makes covert pronunciation and rehearsal an exciting topic of research in cognitive psychology and neuroscience.

Cross-References

► Cognitive Self-regulation
► Sequence Learning
► Sequential Learning
► Short-Term Memory and Learning
► Variation in Working Memory Capacity, Fluid Intelligence, and Episodic Recall

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Covert Rehearsal

► Covert Pronunciation and Rehearsal

Covert Reorganization / Spatial Learning

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Synonyms

Consolidation; Spatial memory; Spatial navigation

Definition

Spatial learning refers to the ability to encode, store, and retrieve information about one's environment and its spatial orientation. For example, spatial memory is required when we have to navigate in a familiar environment or when we have to learn how to go from one point to another in a novel environment. Memory consolidation refers to the time-dependent process by which recently acquired information is gradually integrated into long-term memory stores, a process whose duration ranges from hours to years according to theoretical models, neurobiological and neuropsychological observations. Consolidation of spatial, hippocampus-dependent memories benefits from sleep. However, functional neuroimaging studies have revealed that this process of consolidation takes place by means of a covert reorganization of brain patterns underlying memory performance, which is not necessarily accompanied by overt changes in behavior.

Theoretical Background

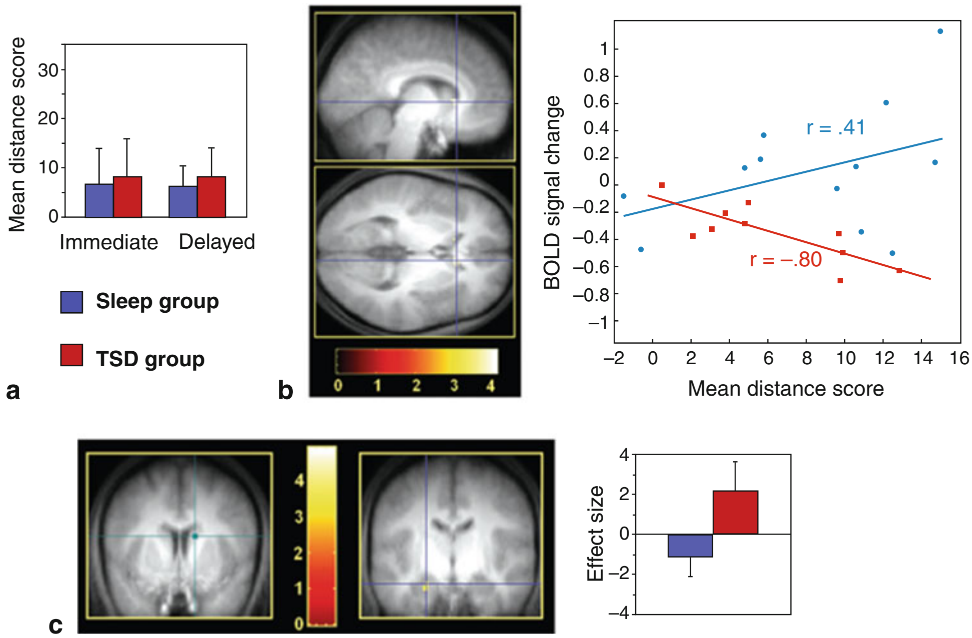
Animal and human studies have demonstrated a primary role for hippocampal areas in spatial learning, supporting allocentric representation of the environment and encoding of the relationships between environmental clues. However, spatial navigation in a well-known environment may also be supported by activity in the striatum through stimulus–response associations. Indeed, whereas a hippocampus-dependent strategy is applied in the early phase of training, a strategic shifting toward striatum-dependent responses may take place after repeated practice (Iaria et al. 2003). Noticeably, active reshaping of brain activity is not necessarily accompanied by overt, detectable change in behavior. For instance, rodent and human studies have yielded evidence for a covert reorganization of spatial memory traces during sleep, a state known to be beneficial for memory consolidation processes. In these studies indeed, the neural basis of performance at retrieval was modified with intervening sleep and/or time after learning, whereas performance levels *per se* were unchanged. In this section, we review those animal and human studies having evidenced covert reorganization of cerebral activity in spatial learning, especially in relation to sleep.

Important Scientific Research and Open Questions

Route retrieval and way finding in a previously learned environment are critical prerequisites to successfully carry out most daily activities. These abilities rely upon a spatial memory system whose description has been greatly improved by rodent studies showing that so-called hippocampal place cells selectively fire when the animal occupies a specific location in its environment, allowing the creation of a spatial map. Noteworthy, several studies have disclosed the reactivation of neuronal ensembles during sleep and wakefulness immediately following exposure to spatial environments. Thus, studies conducted in rodents revealed that firing activity of hippocampal place cells active during spatial exploration behavior was increased during subsequent sleep states. Using large ensemble recordings of place cells in the CA1 field of rodents' hippocampus, it has been further showed that those cells that fire in a synchronous manner when the animal occupies particular locations in its environment exhibited an increased tendency to fire together again during subsequent non-REM (NREM) sleep, as well as during the immediate post-training wakefulness period. Synchronous cellular activity during NREM sleep actually reproduced the discharge patterns observed during task performance, eventually leading to the *neuronal replay* hypothesis, positing that information acquired during active behavior is reexpressed during sleep, a phenomenon that may represent a neurophysiological substrate for memory consolidation processes. Although neuronal reactivations have been repeatedly observed during NREM sleep in rodents, similar phenomena have been also disclosed during REM sleep (see Peigneux et al. 2001 for review), suggesting that all sleep stages may support the processes of memory consolidation. Additionally, it was found that the temporal sequence of neuronal discharges observed in hippocampal CA1 neurons during spatial exploration is repeated – *recapitulated* – during NREM sleep on a similar or faster timescale. Neuronal replay after spatial experience is not restricted to CA1 hippocampal neurons, since reexpression of firing patterns during sleep has been observed also in posterior parietal, visual, and prefrontal cortices (Peigneux et al. 2001). Finally, temporal correlations during NREM sleep between hippocampal ripples (high frequency waves at 140–200 Hz) and spindle activity (phasic bursts in the 12–16 Hz frequency range) recorded in the prefrontal cortex were observed, reflecting coactivation of hippocampal and neocortical pathways. Taken together, offline replay of hippocampal activity together with coactivation of neocortical areas during sleep probably represents important components in memory consolidation processes, allowing a gradual transfer of recently acquired spatial memory traces from short-term hippocampus-based to long-term neocortical stores. Still, it should be noticed that those animal studies have not evidenced behavioral changes following the post-training sleep, putatively consolidating period.

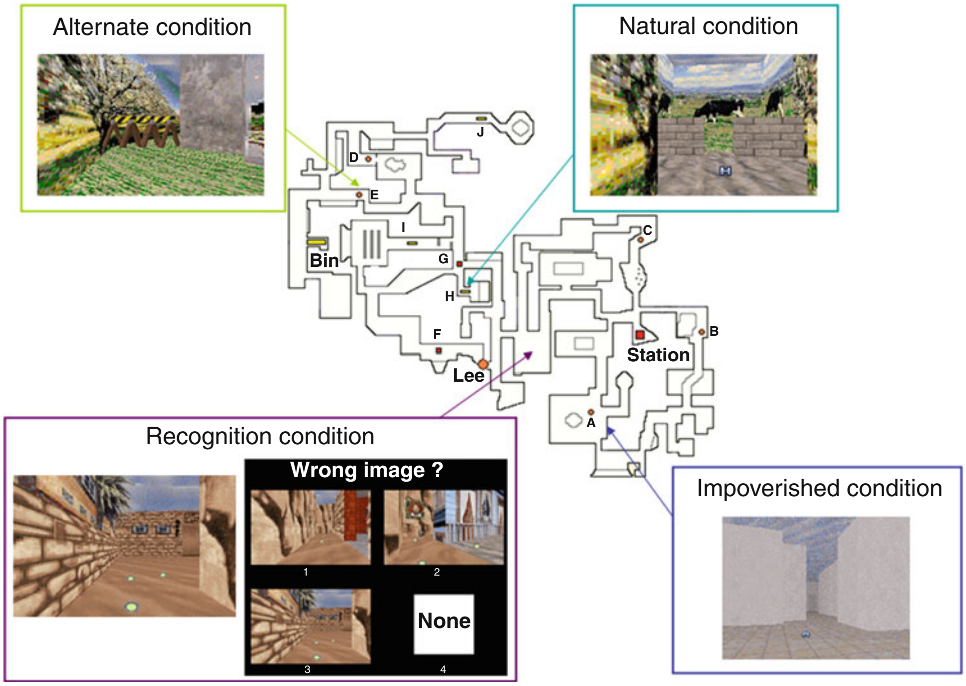
Likewise in humans, post-training reactivation of spatial navigation-related activity has been reported during slow wave sleep (SWS; i.e., the deepest component of NREM) using positron emission tomography (PET) (Peigneux et al. 2004). Furthermore, it was found that overnight gains in task performance were correlated to hippocampal activity levels during SWS, suggesting a close association between spatial memory consolidation and hippocampal reactivation during sleep (Peigneux et al. 2004). In a follow-up study, Orban et al. (2006) investigated using fMRI the sleep- and time-dependent reorganization of spatial memory traces within the brain using a navigation learning task in a complex virtual town with a high degree of details (walls, ground textures, objects,...). In this experiment, subjects were scanned during route-finding tasks immediately after learning (consisting in a free 30 min exploration period) and 3 days later. Then, half of the subjects were allowed regular sleep, whereas the other half was totally sleep-deprived during the first post-learning night. Surprisingly, results showed a striking dissociation between equivalent performance and distinct neural bases for route retrieval at delayed testing in sleep and sleep-deprived participants, suggesting sleep-dependent processes for reorganization of learning-related cerebral activity, not paralleled by overt changes in behavior. Indeed, whereas route finding elicited increased activity in a well-known navigation-related hippocampo-neocortical network (Maguire et al. 1998) at immediate and delayed retrieval testing both in sleep and sleep-deprived participants (Fig. 1), activity in routine behavior-related striatal areas was associated with delayed retrieval activity only in participants allowed to sleep after training. Furthermore, correlations between striatum activity and navigation accuracy were positive in the sleep group (higher activity in the striatum associated with higher navigation accuracy) but negative in sleep-deprived participants (Fig. 1). Likewise, connectivity between hippocampus and striatum regions was negative at delayed retrieval in the sleep group but positive in the sleep-deprived. As a whole, these data suggested that brain activity is reorganized during post-training sleep in such a way that navigation, initially based on a hippocampus-dependent spatial strategy, becomes progressively contingent on a response-based strategy mediated by the striatum (Iaria et al. 2003). In other words, sleep favored the automation of spatial navigation. These results additionally demonstrated that covert (not directly observable) reorganization of brain activity underlying navigation after sleep is not necessarily accompanied by overt (observable) behavioral changes.

It should be kept in mind that spatial navigation is not in itself a pure process, but rather involves many cognitive operations and different memory components including spatial and contextual representations. More precisely delineated, a spatial memory representation involves the creation of and/or the access to a cognitive map of the environment where the spatial relationships between the streets are specified independently of the salient features of the environment. For instance, when attempting to reach the hospital from the supermarket, one can keep in mind an "abstract" map-like representation indicating the appropriate direction to follow at each crossroad, independently of specific environmental cues along the way. Besides this "streets configuration" component however, a second, complementary process can be used, which refers to a contextual memory representation (or "landmarks memory") in which specific associations between salient landmark objects and their milieu are stored. For instance, one may remember that from school to library, there is a right turn just after the post office and then a left turn in front of the church. Thus, a further study wondered whether sleep globally promotes consolidation of all memory components embedded in virtual navigation, or rather favors the development of specific representations (Rauchs et al. 2008). Using the same experimental design than in Orban et al. (2006), participants were administered four memory tasks (see Fig. 2) specifically tapping either the spatial memory component ("Impoverished" and "Alternate" conditions) or the contextual memory component ("Recognition" condition) or both ("Natural" condition). In the Natural, Impoverished, and Alternate conditions, subjects had to retrieve the route between two locations in the



Covert Reorganization / Spatial Learning. Fig. 1 Navigation accuracy and sleep-dependent modulation of brain activity. (**a**) Navigation accuracy, estimated as the distance traveled toward the target location, at the immediate (*left*) and delayed (*right*) retrieval sessions for the sleep (*blue*) and sleep-deprived (*red*) groups. (**b**) Between-group regression analyses of the average session performance on cerebral activity at delayed retrieval (*sagittal and coronal sections*). The blue crosshair indicates the right caudate nucleus. The scatter plot shows that brain response in this area was correlated positively with performance in the *sleep group* (*blue*; $r = 0.41$) but negatively in sleep-deprived participants (*red*; $r = -0.80$). (**c**) Psychophysiological interaction analysis using the right caudate nucleus (*green crosshair*) as seed area. The coupling of activity between the caudate nucleus and the left hippocampus (coronal section) was negative in the sleep group (*blue*) but positive in sleep-deprived participants (*red*). The blue crosshair indicates the left hippocampus. Blue and red plots show the size of effect for each group. Error bars are standard deviations

learned environment. In the Impoverished condition, the environment was plainly deprived of any wall/ground feature and objects, promoting the use of spatial representations to successfully perform the task. In the Natural and Alternate conditions, the environment was the same as during the training period (one hour of free exploration of the environment performed outside the scanner), allowing the use of both contextual and spatial memory representations. In the Alternate condition however, direct pathways between starting and target points were blocked to promote alternative route-finding strategies that rely more on spatial representations. In the Recognition condition, subjects had to pay attention to the environmental features of the town while following dots marking the path between two locations, thus the spatial requirements of the task were minimized while the contextual representations were probed. Subjects had then to determine whether environmental changes were made as compared to the exploration period (Fig. 2). Again, behavioral performance did not differ between participants allowed regular sleep during the post-learning night and those who were sleep-deprived, neither in a natural setting that engages both spatial and contextual memory processes nor when looking more specifically at each of these memory components (Rauchs et al. 2008). At the neuronal level however, analyses focused on contextual memory revealed distinct correlations between performance and neuronal activity. In sleep participants, recognition performance was correlated with activity in frontal regions, suggesting that recollection processes were in use, whereas performance was associated with parahippocampal activity in sleep-deprived subjects, suggesting the involvement



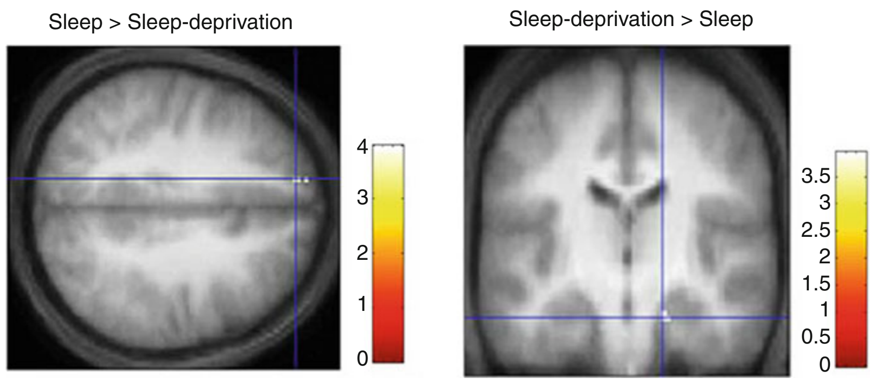
Covert Reorganization / Spatial Learning. Fig. 2 Virtual environment and navigation tasks. The map depicts an aerial view of the color 3D virtual town in which subjects navigated at the ground level using a keypad. The ten possible starting points are represented by letters (from *A* to *J*) with associated symbols and colors indicating the location to reach, out of three possible targets (*Bin*, *Lee* and *Station*). The four snapshots display samples of the environment as seen by the participant in the *Natural*, *Recognition*, *Alternate* or *Impoverished conditions*. For the Recognition task, subjects first navigated in the environment following color dots on the ground (*left panel*). They were instructed to determine whether and where environmental changes had been made as compared to the town explored during the training period. At the end of each walk, a four-choice panel composed of three pictures taken from the path (one of them representing a change made in the environment), and a white square was presented. Subjects had to respond by selecting the modified image or the white square if they thought that no modification had been made (*right panel*)

of familiarity processes (Fig. 3). Likewise, efficient spatial memory was associated with posterior cortical activity after sleep whereas it was correlated with parahippocampal/medial temporal activity after sleep deprivation. Finally, variations in place-finding efficiency in a natural setting encompassing spatial and contextual elements were associated with caudate activity after post-training sleep, replicating our prior study (Orban et al. 2006), suggesting that sleep favors automation in navigation.

To sum up, available data indicate that even in the absence of overt, measurable behavioral modifications following time or sleep after spatial learning, post-training sleep covertly reorganizes the neural substrates of both spatial and contextual memories. Still, the phenomenon is not unique to spatial learning since lack of overt changes in behavior paralleled with covert modulations of brain activity following sleep has been reported also for memory consolidation of emotional material. Although further studies are needed to fully understand the functional significance of covert reorganizations, available data suggest that cerebral reshaping may precede overt expression of behavioral changes.

Cross-References

- ► Human Cognition and Learning
- ► Memory Codes (and Neural Plasticity in Learning)
- ► Memory Persistence
- ► Place Learning and Spatial Navigation
- ► Spatial Learning



Covert Reorganization / Spatial Learning. Fig. 3 Sleep-dependent modulation of correlation between brain activity and performance in the Recognition condition. Contrasts are displayed at $p < 0.001$ (uncorrected) superimposed on the average T1-weighted MR scan. Correlations were computed at the within-subject level (i.e., between brain activity and individual variations in trial-to-trial performance). *Left panel*: higher correlations in sleep than in sleep-deprived participants in the left frontal gyrus. *Right panel*: higher correlations in sleep-deprived than in sleep participants in the right para-hippocampal gyrus

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Covert Speech

► Covert Pronunciation and Rehearsal

Creative Inquiry

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Synonyms

Creativity; Passion; Self-inquiry; Transformative Education; Transformative Learning

Definition

Creative Inquiry frames education as a larger manifestation of the creative impulse rather than as the fundamentally instrumental acquisition, retention, and reproduction of information, or Reproductive Learning (Montuori 1989, 1998, 2005, 2006, 2008). It stresses the role of ongoing inquiry, and the active creative process of bringing forth meaning, knowledge, self, and engagement with the world. Creative Inquiry critiques Reproductive Learning, where the student is an empty vessel to be filled by the instructor, and Narcissistic Learning, which places the individual's largely unreflective and decontextualized opinions, likes and dislikes, at the center of a subjectivist, relativistic world.

Theoretical Background

Creative Inquiry reflects a larger shift in worldview from a Newtonian/Cartesian machine metaphor to the metaphor of a creative universe (Bocchi and Ceruti 2002; Davies 1989; Kauffman 2008; Kaufman 2004; Montuori 1989). In the early twenty-first century, our understanding of creativity itself is being transformed. Creativity is now central to human existence, life, and the Universe. Creativity is not, in the new view, limited to gifted individuals, to a process that leads to a new product, to a revolutionary idea of earth-shaking proportion, or exclusive to specific domains such as the arts and sciences. Creativity is now increasingly seen as a distributed, networked, paradoxical, emergent process that manifests in all aspects of life (Montuori 2011). The fundamental nature of existence, of human beings, and of the Universe itself is creativity, rather than matter (materialism) or ideas (idealism). The inquirer is not a machine or an empty vessel requiring to be filled from the "outside" by a teacher, where the spark of creativity is a rare and mysterious phenomenon. In Creative Inquiry, the inquirer is viewed as engaged in a recursive process of exploration and creation of self and world.

Reproductive Learning reflects educators' borrowing of concepts from the Newtonian/Cartesian machine metaphor applied to the industrial organization of society, coupled with traditional authoritarianism. It was designed to reproduce the existing social order and educate for conformity, hierarchy, division of labor, hyper-specialization, and the quest for certainty (Giroux 2007, 2010; Kincheloe 1993). Creative Inquiry reflects scientific developments outlining the fundamental creativity of the universe, nature, and humanity, and is informed by epistemological perspectives from the sciences of complexity and constructivism (Morin 2001, 2008a). As such it draws extensively on systems and complexity science.

Reproductive Learning privileges analysis, reductionism, disjunction, abstraction, and simplicity. Creative Inquiry strives to illuminate the complexity of the world by fostering the development of transdisciplinary "complex thought" (Morin 2008a, b). It stresses the importance of connecting and contextualizing, and the inquirer is recognized as an embodied and embedded participant rather than spectator to life and knowledge. Inquiry, learning, knowing, and knowledge themselves are viewed as systemic, relational, processual, contextual, and creative processes. A musical metaphor can illustrate the difference between Reproductive Learning and Creative Inquiry. Reproductive Learning is similar to classical Western music after 1800, where musicians learned to play their instruments to perform preexisting musical scores. Creative Inquiry is more akin to jazz. Technical competence is required, but the purpose is to learn to develop the skill of improvisation, and to learn to explore musical themes alone and in collaboration with others. While reading musical notation for certain sections of the performance is necessary, during improvisation there is no preestablished "right" set of notes, but rather an inquiry into the musical text (the song) and context (including fellow musicians, audience, etc.) which can be approached or framed in a plurality of ways to elicit and generate a plurality of meanings (Montuori 2003). Much of the jazz repertoire consists of well-worn standards from the Great American Songbook that have been played by all the great legends of jazz, and yet they can be mined for more interpretations, and more remarkable performances. This process brings forth a collaborative performance that sheds new light on the songs, the performers, and indeed on the listeners, and rekindles the passion that motivates further inquiry and further performance. There is no "ultimate" answer, and no edifice of knowledge that must be built, block-by-block, but rather an exploration of a network of people, events, ideas, beliefs, and assumptions, and the way knowledge is always already embodied and created.

Creative Inquiry integrates the learner and his/her experience, affect, and subjectivity in the learning process, and invites the exploration and if necessary unlearning of social and personal habituations that become unchallenged "givens" and thereby create implicit interpretive frameworks. Creative Inquiry also contextualizes and challenges learning. It situates inquiry in the social, cultural, political, and economic roots and matrices of knowledge, and explores the criteria by which some things are considered knowledge and others not, as well as the creative, constructive process involved in knowledge production. It, therefore, addresses the psychology and sociology of knowledge, as well the philosophy of social science.

The Epistemology of Not-Knowing

Reproductive Learning begins with the assumption the learner is an empty vessel awaiting the delivery of correct knowledge from the instructor. This knowledge must be reproduced to the instructor's satisfaction. Creative Inquiry starts from an attitude of "not-knowing," a willingness to accept the illusion of familiarity that covers the vast mystery of existence, examine one's positions in the process of inquiry, and challenge fundamental and underlying assumptions that shape inquiry. The goal is not to conclude the process by having the correct answer, but to encourage a more expansive, spacious approach to inquiry that actually generates more potential inquiry rather than stopping at the one "correct" answer, and illuminates the creation of knowledge. As in a jazz group, "band members" are invited to make contributions that will make the overall sound of the band the most interesting and surprising. The point of contributions is not to provide "the" answer, and thereby to stop the conversation. In the same way that band members can push a soloist to greater heights with a series of well-placed chords or percussive accents, or simply verbal encouragement, the object of these contributions is to push the dialogue to greater heights and to keep it going (Montuori 2003).

Creative Inquiry recognizes the limitations of knowledge and the opportunities for different perspectives, frames, and approaches. This involves an attitude of epistemological humility and fallibility that recognizes humanity's always partial and limited understanding of the world (Bernstein 1983, 2005). Even more importantly, it also recognizes that not-knowing is a fundamental starting point for creativity. The willingness to be open to the possibility that all knowers have a fallible interpretation of the world allows for the emergence of multiple alternative perspectives rather than the assumption of a fixed "given" world. Creative Inquiry encourages constant exploration and self-examination for attachment to positions, obsession with certainty and power, and a constant awareness of the threats of dogma and/or habituation. Above all, an attitude of not-knowing allows for the space and openness for novelty to emerge.

Creative Inquiry does not accept the common binary opposition between creativity and rigorous scholarship suggested by the Romantic mythology of creativity. This mythology's assumption of "genius without learning," so popular in the West, became Narcissistic Learning. Understood in a wider perspective, the creative process requires and includes discipline, a foundation of skills, and immersion in the field, in the same way that a creative musician must practice scales and learn music theory. But these are not antithetical to creativity. On the contrary, the foundation in scholarship is essential in order for the creativity to emerge (Montuori 2006; Montuori and Purser 1995).

Creative Inquiry (CI) stresses the importance of immersion and active participation in an ecology of ideas, in the existing discourse, literature, and research (Montuori 2005). It also recognizes that embodied and embedded knowing is grounded in existing cultural, social, and historical assumptions, theories, facts, and beliefs, and that any action in the world is based on, and in fact cannot occur, without interpretations of the world and specific situations. This knowledge is necessary for participation in both discourse and practice. For Creative Inquiry this knowledge, in the form of paradigms, theories, etc., shared by communities of inquiry (fields, disciplines, research methods, and agendas), and the inquirer's own implicit assumptions and theories, is itself constantly the subject of inquiry, offering an opportunity to explore and understand the creation of knowledge, perspectives, positions, beliefs, theories, for purposes of wise and creative action.

Important Scientific Research and Open Questions

Culturally and philosophically, Creative Inquiry emerges as an effort to address the opposition between Objectivism and Relativism (Bernstein 1983, 2005). With (objectivist) Reproductive Learning, the deterministic assumption is that the environment, "objective reality," creates the learner. In (subjectivist) Narcissistic Learning, this assumption is reversed, and captured in the popular New Age dictum "I create my own reality." Creative Inquiry proposes a recursive relationship where "I create a world which creates me." Creative Inquiry is an ongoing creative process in which the inquirer is engaged in self-eco-creation (Montuori 2003; Morin 2008a). Creating not just himself or herself, but creating a relational being whose actions have an impact in an interconnected, interdependent social and natural context. This is a crucial difference with Reproductive Learning, where the learner is treated like an isolated cog, to be molded by the educational process, so as to fit in a larger machine.

Much important research still needs to be done in the application of creativity, complex thought, and co-constructivist epistemologies to education, building on the works of Morin, Kegan, Kincheloe, Varela, and others. Central to this research will be the role of the inquirer in inquiry and the strong parallels between Formal Thinking (Reproductive Learning) and Post-Formal Thinking (Creative Inquiry). Creative Inquiry's improvisational dimension is also akin to the concept of expertise from Dreyfus and Dreyfus's research (Montuori 2003).

Inquiry and/as Self-Inquiry

Creative Inquiry invites inquirers to explore what they are passionate about, and to ground their work in this passion. This passion itself becomes a topic for inquiry and self-reflection as inquiry becomes an opportunity for developing self-knowledge. The inquirer is not a spectator to the world, but embodied and embedded, an active participant in knowledge-creation and praxis. Particular attention is paid to espoused theory and theory-in-use, to dialogue between the inquirer's views and the research literature, and through dialogue with the perspectives of other co-inquirers. Every inquiry becomes self-inquiry in an ongoing process of unearthing one's own implicit theories and assumptions, and in turn how they may be related to one's own personal history, sense of identity, attachments to beliefs and ideologies, and so on.

A central dimension of Creative Inquiry is the self-reflection on this creative process of knowledge-making and knowledge-embodying. Knowledge and concepts are viewed as creative products of the human mind (Deleuze and Guattari 1994) that can be challenged and opened up to reveal underlying assumptions and the way they define, organize, and determine knowledge. Theories, frameworks, and so forth illuminate some dimensions of the world and obscure or ignore others, and are inevitably limited and partial. CI views concepts as creative products. It frames inquiry into concepts (theories, paradigms, beliefs, etc.) and actions (as embodiments of theories, paradigms, etc.) as inquiries into the creative process of concept-creation. CI is *radical* in the sense that it addresses the underlying roots and matrices from which knowledge emerges, as well as the organization of knowledge and knowledge of organization.

The process of self-creation through Creative Inquiry is not relativistic, self-centered Narcissistic Learning, revolving around the learner's subjective likes and dislikes, agreements and disagreements, but an integration and embodiment of the inquiry process in a practice of *phronesis*, defined in this context as wise action informed by a (self-) reflection on values, beliefs, and implicit theories. Given the assumption that creativity is not an exceptional talent confined to a gifted few but rather the essential condition of all human beings, the question becomes *how* that creativity will be utilized and for *what* purposes. Self-creation in CI, therefore, means taking responsibility for creativity and addressing central questions pertaining to the "who," "why," and "to what end" of inquiry. Inquiry is not a dispassionate, purely "objective" process any more but engagement, participation, and responsibility for creation. It is an action in the world, and as such has repercussions in the world and ethical consequences, as well as being motivated by human passions and social, political, and economic dimensions.

Cross-References

► Creativity and its Nature
► Narcissistic Learning
► Reproductive Learning

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Creative Leap

▶ Mental Leap

Creative Problem Solving

▶ Creativity, Problem Solving, and Feeling

Creative Thinking

▶ Collaborative Learning and Critical Thinking

Creative Thinking in Music

▶ Composition Learning in Music Education

Creativity

▶ Composition Learning in Music Education
▶ Creative Inquiry
▶ Imaginative Learning

Creativity and Its Nature

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Synonyms

Ingenuity; Innovation; Inspiration; Inventiveness; Originality

Definition

Creativity has traditionally been seen as an ability to respond adaptively to the needs for new approaches and new products. It is often defined as the ability to bring something new into existence purposefully. The concept of creativity has expanded and changed in the last decade. In the sciences, creativity is increasingly being viewed as intrinsic to the very nature of the Universe. A new emphasis on "everyday" and "social" creativity is shifting the focus from individual genius in rarified fields (fine arts, advanced science) to collaborative creativity in everyday life, with implications for learning and education that are only beginning to be explored.

Theoretical Background

Historically, creativity has not been fostered in educational contexts (Plucker et al. 2004; Robinson 2001). Until the twenty-first century, this was largely because creativity itself was poorly understood, and because creativity is generally associated with disruptions and challenges to the existing order. Creativity was not considered a phenomenon that could be scientifically explained or fostered, and there was also no sense that creativity was an essential capacity and competence for human beings. The importance of creativity has become prominent for a number of reasons, including its adaptive nature for individuals and societies in a rapidly changing world. Driven by a combination of post-materialist conditions in many technologically advanced countries and the explosion of the discourse of self-help and personal growth, there is also an increasing desire for self-expression and self-creation as individuals break out of traditionally established careers and life-paths. It is also often the case that with rapid technological and economic change, many new professions are emerging as old ones become obsolete and fall by the wayside. Individuals and communities therefore have to reinvent themselves. Self-creation has become a major societal process where creativity takes center stage (Bauman 2008).

The concept of creativity emerged in the West in the Renaissance, along with individualism, and blossomed with the Genius myth of Romanticism. Until the 1980s, research on creativity in the West focused primarily on the three Ps: Person, Process, and Product (Runco 2007). In the romantic mythology underlying this atomistic view, the creative person was mostly a lone, eccentric genius. The "Who" of creativity could therefore *only* be an individual person. Groups, organizations, cultures, and relationships were representatives of conformity and compliance, and were mostly viewed as potential obstacles.

The "How" of creativity consequently occurred exclusively "inside" the individual. The classic image of the creative process involved a light bulb going on over the creator's head during the Eureka moment. The creative process was viewed as a solitary process, initially with mystical or divine sources, and then also increasingly associated with mental unbalance or even psychopathology. The focus of the How was on the generation of the idea, not the process leading up to the idea or how the idea would become a reality. The "What" or creative product was associated with "big bang," earthshaking insights (Montuori and Purser 1999; Runco 2004, 2007). Educational institutions and educators were not meant to cultivate the insights of genius, but merely to reproduce a certain foundational knowledge base and social system. The "Where" of creativity was almost exclusively the arts and sciences, and in the latter mostly physics (Montuori 2011).

If having the Creative Person as the unit of analysis *by definition* ruled out creativity as a possibility for educational settings, the Where of creativity by definition made it virtually impossible for somebody not in the arts or science to consider herself creative or to be engaged in an enterprise that was labeled as creative by others. This meant that creativity could only "exist" in a limited number of human activities. In the West and many other parts of the world, women were traditionally not given extensive access to these activities. For example, in the arts, no musical performances in public, no study with nude models, and in the sciences, limited access to education and explicit exclusion from many areas. Women were therefore not in a position to be considered creative because they simply could not participate in the activities that were societally labeled as creative (Eisler and Montuori 2007). This characterization of creativity therefore made it a very unusual, subjective, contingent phenomenon that was limited to very few individuals during rare moments of inspiration in a closely circumscribed set of human endeavors.

Creativity was a puzzling phenomenon in Modernity. The Modern scientific worldview was based on a machine or clockwork metaphor in which the world was fundamentally Objective, Rational, and Orderly. Creativity on the other hand was either associated with subjective experience, the irrationality of mystical insight or a breakdown in Order and hence with Disorder, whether socially or personally (mental illness, revolution). Creativity was viewed as essentially contingent and subjective, rather than a lawful, orderly, and objective phenomenon. Science itself could therefore not account for creativity. The creativity of scientists did not begin to be systematically addressed until the 1950s as part of the larger emergence of systematic creativity research. In his important work *The Logic of Scientific Discovery*, philosopher of science Karl Popper stressed the context of justification, and did not in fact discuss discovery itself, which was, because of it subjectivity and contingency, not considered amenable to scientific inquiry. By leaving the context of discovery to psychologists, he was essentially dismissing it as a worthy subject for science and philosophy, and hence serious inquiry (Popper 2002).

Mainstream education mostly did not address creativity, because it was considered a gift of unique individuals rather than a quality or characteristic that could be cultivated, and also because the social and political purpose of education was to create good law-abiding citizens and workers, not independent thinkers. When the systematic and scientific study of creativity by psychologists was ushered in by J.P. Guildford's Presidential address at the American Psychological Association meeting in 1950, this was part of a larger Cold War climate. The main concern was to reestablish American scientific supremacy. No effort was made to foster creativity in all students. Greater attention was paid to creativity by finding the "best and the brightest" so they could be given special attention and their gifts nurtured.

Despite the now truly substantial research literature on creativity (Runco 2004, 2007), its impact on education has been slim. At the beginning of the twenty-first century, numerous critiques of education across all levels bemoan the lack of creativity, and the focus on Reproductive Learning that stresses memorization, test-taking, and conformity (Robinson 2001). In the USA, the Ph.D. dissertation is supposed to be an original contribution to one's field, but tellingly originality and creativity are barely ever discussed during the educational process, unless it is in the context of plagiarism (Montuori 2010). Research on the difficulties American doctoral students have completing their degree found that in large part, the educational system simply does not prepare students to be independent researchers (Lovitts 2005).

Important Scientific Research and Open Questions

There are strong indications that in the twenty-first century, the discourse and practices of creativity itself may be changing. From the Modern individualistic focus oriented to "eminent" or uncontroversial creatives producing exceptional products (Einstein, Picasso, etc.), there has been a shift toward a more collaborative, "everyday," ecological creativity. The focus is on generative interactions in a variety of mundane contexts, rather than the individual lone genius. Millennial college students associate creativity with everyday activities, and with social interaction. Whereas for Baby Boomers, creativity came from "eminent creatives" in the form of the guitar of Jimi Hendrix or the pens of Herman Hesse or Thomas Pynchon, in today's "participatory" culture (Jenkins 2009), the focus is not so much "eminent creatives," but participatory processes in video games like Beaterator, and the Garageband music application.

The new, contextual and collaborative approach to creativity by the younger generation is matched in the research by a new research interest in the social dimensions of creativity (Montuori 2011; Montuori & Purser 1999). There is a move away from an essentialist view of creativity to one that is relational and contextual. The emphasis on these dimensions of creativity may be significant for education. Traditionally fostering creativity meant removing exceptional students from their educational context. Their exceptional nature was the starting point, but essentially the result of contingency and individual characteristics, and not replicable. Historically, there has been little research on the creation of environments that foster creativity across the board for all students (Amabile 1996). The focus on the social dimensions of creativity is showing that creativity is also a function of certain kinds of environments.

Creativity has been consistently mythologized and misunderstood. Educational attempts to go beyond traditional Reproductive Learning and foster creativity have at times veered perilously into Narcissistic Learning, valorizing the subjective, the unusual, and self-expression at the expense of traditional competencies. Typical was the left brain/right brain fad of the 70s and 80s. It seemed to suggest that the "right brain" (the non-dominant hemisphere) was all that was needed for creativity, and the "left brain" was simply a hindrance. Research conclusively shows that creativity involves both hemispheres. Yet it is the simplicity of the right brain explanation that is so appealing and also so misleading. The underlying dichotomizing is the same kind of thinking that leads to Narcissistic Learning and the promotion of a trivial creativity that is exclusively self-expressive but not contextually appropriate. Indeed when creativity is viewed through a binary logic and decontextualized, it is trivialized and mutilated.

The emerging research on and practices of creativity can be summarized as proposing that:

1. Creativity is the fundamental nature of the Universe, the process of creation itself, rather the spark of an occasional (C)creator, and is therefore a basic "everyday, everyone, everywhere" human capacity.
2. Creativity is a networked, ecological, and relational process rather than an isolated phenomenon.

3. Creativity is paradoxical; in the characteristics of the creative person, process, product, and environment are found seemingly incompatible terms: Creativity requires *both* order and disorder, rigor and imagination, hard work and play, idea generation and idea selection, times of introspection and solitude and times of interaction and exchange.
4. Creativity is an emergent process arising out of interactions of a given system and therefore unpredictable.

The challenge facing education is to integrate the new creativity research, and at the same time recognize that creativity should not merely be an interesting or appealing "add-on" to education, situated mainly in the arts, but that it should in fact be at the heart of education (Montuori 2010).

Cross-References

► Creative Inquiry
► Narcissistic Learning
► Reproductive Learning

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Creativity and Learning Resources

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Synonyms

Creativity program; Creativity training

Definition

Two main approaches can be followed in order to lead people to learn to be creative (Parnes and Harding 1972). The first approach originates from suggestions provided by progressive and active pedagogies and, more specifically, by learning through discovery. The main purpose is to arrange learning settings to induce individuals to express personal ideas, to freely imagine unusual situations, to look for new and not obvious solutions to problems. Usually no specific materials are devised for these aims; educators are generally invited to modify traditional ways of managing learning activities by paying attention to their attitudes and communication styles, so to create a climate which facilitates learners' expressivity and ideational fluency (Barron 1968). The second approach consists in employing sets of exercises useful for stimulating creative forms of thinking. For instance, learners are asked to devise several ways to use a given tool, to figure out possible ends of an uncompleted tale, to find alternative linguistic expressions for the situations described. Funny games, curious experiments, and practical trials are employed to stimulate creativity (e.g., De Bono 1985), sometimes through the manipulation of concrete materials, graphical signs, and visual patterns.

Theoretical Background

Six main questionable assumptions seem to be shared by many of the past attempts to enhance people's creativity:

1. Creativity consists of a unique mental mechanism; thus, people can be trained in such a single

mechanism. For instance, a single creative technique like brainstorming (Osborn 1957) – one of the best known creativity techniques, focused on the free, abundant production of bizarre ideas in order to promote innovation – could be used as a general tool for developing creative ideas and skills.
2. Trainees are like a *tabula rasa*, that is, before being instructed, they know virtually nothing about how to be creative; they have no idea or opinion about creative strategies and are not able to control them. All this has to be "imprinted" into their allegedly empty minds.
3. Even though trainees are instructed with non-ecologically valid materials (such as puzzles, riddles, and so on), the training programs can succeed in prompting the subsequent spontaneous transfer of creative strategies to everyday situations.
4. The development of creative thinking can be induced by simply asking trainees to perform a specific mental operation a given number of times. In other words, getting some practice in executing an operation should be sufficient to allow people to learn it.
5. Creativity is only a matter of cognitive processes; therefore, trainees must be taught only to activate particular kinds of cognitive operations, without any reference to the complex interaction of these operations with other cognitive processes, emotion, motivation, and the context.
6. Creativity can be promoted as a general ability, without making reference to specific domains.

Given these assumptions, it is not surprising that the traditional programs designed to stimulate creativity often failed to reach their goals. In fact, ordinary situations where creative thinking is needed are usually complex situations that involve multiple mental operations. Furthermore, in everyday life explicit hints to employ the relevant strategy are seldom given, so that individuals need to be able to identify the specific features of the situation in question and choose the appropriate way to deal with it. Finally, individuals must not only *know* how to think creatively, but also must *want*, that is, be inclined or motivated, to process situations creatively. These remarks stressed the need for a different approach to promote creativity. More precisely, various components have to be identified in creativity; more attention to common reasoning and to complex real-life situations is required; the role of metacognition in the acquisition of new competencies has to be highlighted.

Important Scientific Research and Open Questions

In order to produce in trainees a stable aptitude to think and behave creatively in extra-training contexts, it seems that educational tools should:

1. Develop an integrated structure of various mental mechanisms, each playing a role in a particular kind of situation or in a particular phase of the creative process
2. Use materials that mimic real-life situations or, at least, help trainees to recognize the relationship between the training tasks and such situations
3. Consider individuals' spontaneous beliefs and tendencies toward creative thinking and start teaching from their naïve creative competencies, with the hope of changing spontaneous beliefs, tendencies, and strategies by means of an internal restructuring process
4. Show a metacognitive sensibility, that is, train learners not only to execute creative strategies, but also to control their execution (for instance, to select the strategy to be applied and to monitor its application)
5. Encourage a creative attitude, e.g., encourage learners to accept the risks and discomforts that creativity involves, to avoid the tendency to stick to familiar responses and to induce students to look for novelty

Various attempts to integrate cognitive, emotional, and personality aspects of thinking have been made. A constructivist point of view – aimed at substituting the spontaneous beliefs and tendencies of an individual with new and evolved strategies by means of an internal restructuring process – is shared by many contemporary creativity programs. The features of current training materials are in agreement with the issues discussed previously. First, they induce individuals to learn a set of reasoning strategies that can result in a creative way of thinking. Further, they make people aware of the strategies they employ, of their relevance, of their benefits and costs. In other words, the programs stimulate a metacognitive attitude. They also try to encourage autonomy in the management of thinking strategies. Moreover, the critical situations where learners are trained to be creative are real situations or have obvious counterparts in real life. Finally, the application of a given thinking technique is linked to the development of a corresponding attitude, such as: to be open to the experience, to recognize the emotional states, to look for novelty, or to accept contradictions.

Experimental investigations carried out to test the validity of such training materials generally showed that a larger increase of creativity scores is found in the training conditions as compared to the control conditions. Learning materials are more effective when implemented by ad hoc instructed educators, who were trained to control their feeling, attitudes, and communication patterns. In general, a clear superiority of well-structured programs over simple and isolated tasks emerges. In particular, highly creative individuals increase their creativity levels only when a well-structured intervention is carried out by expert trainers (Antonietti 1997). In conclusion, people can learn to be creative. Such learning is possible, however, only if educators employ instructional materials that are consistent with the complex nature of creativity stressed by recent research and that involve learning procedures that are not based simply on repetitive activities. To do so, training materials should allow learners:

1. To know various creative strategies and the conditions under which each of them is adequate
2. To be aware of the mental operation that they are activating in order to monitor its application
3. To recognize the attitudes and emotions that accompany the implementation of a creative strategy and to adopt such attitudes and emotions

The final message that can be drawn from recent investigations is that a particular learning environment is needed and that creativity requires a global involvement of individuals, who should be taught to manage by themselves the mental mechanisms that promote creativity (Gardner 1991).

Cross-References

- ► Analogy/Analogies
- ► Climate of Learning
- ► Curiosity and Exploration
- ► Flexibility in Learning and Problem Solving
- ► Measurement of Creativity
- ► Problem Solving Teaching

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Creativity in Music

► Composition Learning in Music Education

Creativity Program

► Creativity and Learning Resources

Creativity Test

► Measurement of Creativity

Creativity Training

► Creativity and Learning Resources

Creativity, Problem Solving, and Feeling

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Synonyms

Affect; Cognitive and noncognitive processes; Creative problem solving; Intuition

Definition

The terms "► creativity," "► problem solving," and "► feeling" are used in scholarly writing of psychology in ways similar to that employed in popular writing but with some refinement. Derived from the Latin *creatus* "to make or produce," creativity is defined as "the production of effective novelty." The word production implies that some act or action is involved. Thus within the field of cognition, the act of creation or the creative process is studied. However, other psychological orientations such as the "creative person," the "creative product," and the "creative environment" are also investigated. Central to each orientation however, is the assumption that the novelty produced is useful and meaningful. Thus for example, the creation of a scientific idea may be considered useful, the creation of an artistic work meaningful.

Within the cognitive tradition, the term "problem-solving" refers to the set of thinking processes or actions involved in the solving of a problem. Problems may be routine or novel. Routine problem solving involves moving from a given state to a goal state based on a solution plan primed from similar past experiences. In contrast, novel problem solving entails the problem solver moving from a given state to a goal state by inventing the solution procedure. Within the field of creativity research, the problems to be solved are assumed to be novel.

The term "feeling" refers to an element of the affective domain. It may be interpreted to mean a sensing of a physical and or cognitive state and may be sharply or vaguely experienced depending on context. Thus one may not only have a feeling of an emotion but also a feeling of cognition (i.e., feeling about thinking) concerning a particular entity, activity, or event. Feelings of cognition arise in concert with mental processing that may be conscious or nonconscious and occur simultaneously or successively. It is to this feeling of cognition within the context of a creative problem-solving situation that the current entry refers.

Theoretical Background

The theoretical relationship between creativity, problem solving, and feeling is not a simple one and necessitates understanding changing theoretical perspectives on the nature of creativity and how to undertake its research. After all, innovation and enterprise depend for their success on the development of new ideas. But from where do new ideas come? How do they arise? Do feeling and intuition have a part to play? Finding answers to questions such as these represents within itself a unique set of novel problems, problems which have lain at the heart of creativity research for more than 50 years.

Following the dropping of the atomic bomb and the advent of the cold war period during the last century, the identification and selection of creative individuals, particularly within the domain of mathematics and science were seen as a means of fast tracking Western nations into a place of technological advantage. Thus, the secrets of novel problem solving were to be unraveled through studies of the creative *person* capable of generating a creative *product (*viz: the high end, genius, or "big C" creativity). However, the early findings of large-scale investigations proved confounding (as Terman's studies attest) and the nature of creativity proved itself to be more complex than first thought and so this initial flurry of research activity waned (Taylor 1988).

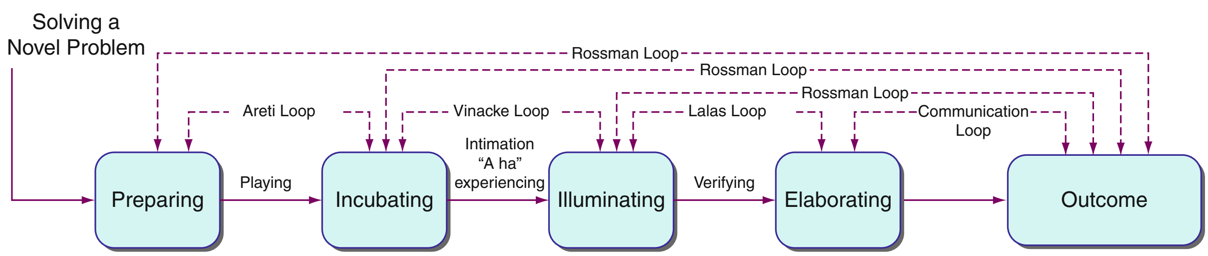
The rapid expansion of information and communication technologies during the final decades of the twentieth century and into the twenty-first century however, together with the growth of business and industry in a globalized market place has once again seen the reemergence of creativity as an important field of research. Working this time from a more egalitarian perspective, that perceived creativity as being not just for a favored few but for everyone (Viz: the small end, everyday, "little c" creativity) the foci of creativity research grew to encompass aspects of the creative *environment* and the creative *process* and their interactions. Creativity, it is noted was to offer hope in finding workable solutions to complex problems. Consequently, interest in creativity in the education sector has proliferated as Guilford had previously foreshadowed. Writing in the inaugural issue of the *Journal of Creative Behavior*, Guilford (1967 p.13) propounded that "creativity is the key to education in its fullest sense and to the solution of mankind's most serious problems."

Of particular note has been the proliferation of *process* models of creative problem solving spurred on partly by business and industry in which education has played a part. Building on the classic stage model (Wallas 1926) which included the phases of preparation, incubation, illumination, and verification have been Shaw's (1989) model of the "Eureka process," Finke et al.'s (1992) "Geneplore" model, Amabile's (1996) "Componential" model, and Cropley's (2001) "Holistic" model to mention but a few. Some of these process models expand upon the number of stages given in the classic model, while others collapse them into broader categories preferring instead to describe a wider range of substages or processes. However of these process models mentioned, only two of them (viz: Shaw and Cropley) highlight the role of affect in the creative process. Interestingly, Shaw identified a series of feedback loops arising between each phase of the classic model and linked them to a set of affect states both positive and negative in the creative process. Each loop was named after the creativity researcher responsible for theorizing its presence. While Shaw hypothesized the presence of five such loops (including the "Rossman loop" that feeds back from all previous stages in the model), he speculated the presence of many more. The proposed existence of multiple feedback loops, operating simultaneously and successively, both consciously and non-consciously, over *n* parallel paths, is consistent with neural network models of the brain. A diagram showing Shaw's feedback loops superimposed onto the classic model of creative problem solving is given in Fig. 1.

Important Scientific Research and Open Questions

However, despite the rhetoric, or perhaps because of it, the question still remains as to why creativity defies complete explanation and why its nature continues to remain elusive. Working at a macroscopic level of analysis, recent research would seem to indicate that a confluence of components is needed involving many orientations (Sternberg 2005) requiring a range of methodological approaches (Mumford 2003) and incorporating different disciplinary perspectives. Reporting on a series of investigations conducted into the nature of scientific creativity more than half a century ago, Taylor (1988, pp. 99) concluded that "creativity is a very complex human performance" involving "all aspects of a person's response repertoire." Such a response repertoire, must by definition involve both cognitive (thinking) and noncognitive (feeling) components. Traditionally however, the field of cognitive psychology has focused solely on the cognitive processes. This begs the question "What makes creative problem solving creative?"

At a microscopic level of inquiry, recent advances in neuroscience have shed new light on the role of noncognitive processes in human reasoning and consciousness, revolutionizing thinking concerning the role of feeling and intuition in solving novel problems. Working with brain-damaged patients, Damasio (1994) found individuals, who having presented with normal IQ, language ability, and learning capacity, being unable to solve problems, due to impairment of the feeling function within the brain. Damasio goes on to describe three kinds of feeling, notably feelings of basic universal emotions, feelings of subtle universal emotions, as well as background feelings. These feelings arising from the complex interplay of the brain core (viz: hindbrain, midbrain, and limbic systems) and the cerebral cortex, provide a picture of the body's internal state justa-positioned with information received about the external one. Such feeling is essential to human survival and consciousness. According to Damasio, feelings are just as cognitive as other precepts and are essential for being able to move through a decision



Creativity, Problem Solving, and Feeling. Fig. 1 Diagram of the classic model of creative problem solving superimposed with Shaw's feedback loops making space. Thus, while the traditional view may have been that feelings interfere with an individual's ability to solve problems, this old adage failed to point out that in the absence of feeling an individual is unlikely to solve the problem at all.

Evidence of individuals attending to a feeling of cognition in solving novel problems is to be found in the historical accounts of notable scientists and mathematicians. Henri Poincaré, for example, describes an inner aesthetic feeling guiding his response to a new intellectual order, Albert Einstein describes a feeling of direction sensed visually, going toward something concrete, while Nobel Prize winner Barbara McClintock, describes a feeling of affinity guiding observation into the making of new "insights." In each of these examples, attention to feeling is integral to the creative problem-solving process and the development of new ideas.

In the light of evidence such as this, it is perhaps interesting to note the findings of a recent large-scale study of creative problem solving indicating that students who attended to a feeling approach to reasoning were more likely to be successful in solving a novel mathematics problem than those who did not. In this study, it was inferred that feelings of cognition served to assist the successful novel problem solver through the problem-solving space (Aldous 2009).

Any discussion about the origin of ideas and the solving of novel problems, however, would not be complete without making mention of the debate concerning which process arises first, feeling or thinking. One group of proponents contend that noncognitive (feeling) and cognitive (thinking) processing operate as independent systems and that decisions can be made instantaneously based on a judgment of feeling. Another group of proponents argue that cognitive processing or appraisal always precedes a noncognitive response and by inference therefore all responses are initially cognitive.

On the face of things it would seem that both proponents cannot be correct. However in the light of rapid new developments in the fields of cognition and neuroscience where the human brain, in response to both the environment and the activities of the mind, is found to change second by second Horstman (2010), it may well be that both proponents are correct. What is needed is a broader more interdisciplinary understanding of how the mind, brain, and body function in concert to express a whole raft of mental processes be they cognitive or not.

Cross-References

► Complex Problem Solving
► Consciousness and Emotion
► Problem Solving
► Nature of Creativity

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Credibility Judgments

► Children's Critical Assessment of the Reliability of Others

Crime

► Delinquency and Learning Disabilities

Criminal Autistic Psychopathy

► Diagnosis of Asperger's Syndrome

Crisis Incubation

► Barriers to Organizational Learning

Criterion-Referenced Assessment

When a student's performance is assessed according to how well the performance meets certain preset standards or criteria. This is as opposed to norm-referenced assessment (NRA) that assesses a student's performance accordingly to how well it compares with those of other students.

Cross-References

► Learning Criteria, Learning Outcomes, and Assessment Criteria

Critical Discourse

The confirmation by the learner of a best judgment by discussing assumptions, realizations, and solutions with other adults.

Critical Discourse Analysis

Also known as CDA, is a form of discourse analysis that focuses on the ways in which discourses serve as means of social and political domination. Developed in the last decades by Norman Fairclough, CDA is an interdisciplinary approach unified by foundational assumption about the links between language and power rather than by a well-defined set of analytic techniques.

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Critical Events in Learning

► Critical Learning Incidents

Critical Learning Incidents

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Synonyms

Critical events in learning

Definition

Critical learning incidents are learning situations which learners have experienced as effective, exceptional, or personally meaningful. Critical learning incidents may lead to educationally significant learning and personal growth. The term *critical* refers to the fact that the circumstances described in the incident play an important role in determining the outcome of learning. Typical of these experiences is that critical characters of an incident are described by the learners themselves. This means that incidents include a multitude of different kinds of activity and that incidents can only become critical afterward.

Theoretical Background

The study of critical incidents has a long history in psychology (Butterfield et al. 2005). Flanagan (1954) developed the critical incident technique (CIT) during World War II as a means to gain understanding of the causes of airplane crashes. In 1954, Flanagan published an article on the critical incident technique, describing the origins of the method and a flexible set of principles which must be followed in order to capture a detailed description of the incident. According to Flanagan, a critical incident is any activity that is sufficiently complete in itself to permit predictions to be made about the person performing the act (Flanagan 1954, p. 335). To be critical, an incident must occur in a situation where the purpose or intent seems fairly clear to the observer. The critical incident technique presumes that participants' general assumptions are embedded in, and can be inferred from, their specific descriptions of particular incidents.

Recently, the study of critical learning incidents has been based on the assumption that in order to understand human learning, we should better take into account both personal experience and social context as the most essential factors of the learning process. Hofer and Pintrich (1997) have assumed that the traditional research methods in learning might predetermine approaches of the learning study to focus on the dimensions important for the researcher and exclude more personally salient perspectives. For example, when studying learning from the learner's point of view, students' short stories might better describe their ideas about learning, rather than just asking them to define the concept of learning. In stories, students have to locate their learning experience in everyday situations and to describe it from their personal point of view. When learning is described in the form of a story, it is constituted as a changing, contextual, and personally meaningful sequence of events. In the study of critical incidents, narrative metaphor may be used from the retrospective perspective. That is, students construct their experiences about learning afterward into the shape of a story. Learning itself may be a chaotic or unconscious process, but through telling their experiences, students give logical form to their idea of the process of learning.

Contribution to the Field of Learning

In recent years, the educational power and usefulness of critical learning incidents has become evident for many researchers. Critical incident studies have been used as the basis for curriculum design in many areas of health sciences, teacher education, and the service industry. According to Brookfield (1994), the advantage of the critical incident method in the field of learning is that the emphasis is on specific situations and incidents. Instead of writing about abstract concepts, respondents concentrate on describing particular happenings, which are much easier to report than are general definitions or underlying assumptions. An additional advantage of the critical incident technique is that subjects are talking about themselves without being consciously aware of it. While students are not being asked directly to articulate their ideas or conceptions of learning, the choice of examples really reveals essential features about their own ideas and experiences of learning.

Woods (1993) has reported several benefits that critical incidents possess for the understanding of the nature of student learning. In critical incidents, learning is integrated in the self, because it is based on students' personal needs and goals. Through personal experiences, students have a real possibility to construct their own view about reality. Learners also have a large amount of control over their own behavior in learning settings. In other words, students are the owners of the products of the learning process.

The benefit of critical incidents in the analysis of learners' personal views on learning is twofold. Firstly, they give insight into learners' everyday practices. Secondly, describing specific situations, events, and people is much less demanding or threatening for students than being asked to define their general assumptions about or abstract definitions of learning. Brookfield (1994) believes that the critical incident technique is especially appropriate for teachers or other people who are interested in developing the learning of others.

Important Scientific Research and Open Questions

The benefit of critical incident studies rests on the assumption that concrete learning experiences offer an adequate way to understand learning from the learner's point of view. However, the investigation of critical learning incidents has many methodological challenges. According to Butterfield et al. (2005) the future of critical incident studies is "rooted in the past, which entails striking the right balance between respecting technique's method as articulated by Flanagan(1954), and embracing its inherent flexibility that allows researchers to adapt it for use across myriad disciplines and research questions" (p. 489).

Cross-References

- ▶ Beliefs About Learning
- ▶ Critical Learning and Thinking
- ▶ Everyday Learning
- ▶ Experiential/Significant Learning (C. Rogers)
- ▶ Flow Experience and Learning
- ▶ Learning in Practice and by Experience
- ▶ Transformational Learning

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Critical Reflection

The examination of the influences around oneself that contribute to a worldview change.

Critical Self-Reflection

The examination of the influences around oneself that contribute to a worldview change as they apply to oneself and one's worldview.

Critical Thinking

Process of evaluating the accuracy, credibility, and worth of information arguments individual differences in the disposition to think critically have been observed.

Cronbach, Lee J. (1916–2001)

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Life Dates

Lee Joseph Cronbach was born in Fresno, California, on April 22, 1916. He received a master's degree from the University of California at Berkeley. Thurstone's work on the measurement of attitudes had a strong influence on him, and accordingly he studied psychology at the University of Chicago. In 1940, he received his PhD in educational psychology from the University of Chicago, where he met Ralph Tyler and became his research assistant on the Eight-Year Study – one of the most influential studies in education of that time. Cronbach's lifelong interest in education likely had its origins in this collaboration. In 1940, Cronbach accepted an assistant professorship in psychology at Washington State University. Toward the end of World War II, he served as a military psychologist in San Diego and became increasingly engaged in instructional psychology. After the war, he returned to Chicago, then he moved to the University of Illinois in 1948, and finally to Stanford University in 1964, where he served as Vida Jacks Professor of Education until his retirement in 1980. Cronbach died of congestive heart failure in Palo Alto on October 1, 2001.

As an educational psychologist he made significant contributions to psychological testing and measurement as well as to instructional psychology (Shavelson 2009).

Theoretical Background

As a student Cronbach was highly attracted by Thurstone's work on measuring attitudes, and he was particularly impressed by "Thurstone's inventive use of mathematics to sharpen the central construct and ferret out equivocal items; the virtue of rigorous engineering analysis of psychological measuring devices became fixed in my mind" (Cronbach 1989, p. 65). Furthermore, Cronbach was also highly influenced by Ralph Tyler and his educational research. His research can thus be classified into the main areas of testing and measurement theory, the evaluation of educational programs, and the instructional idea of aptitude–treatment interactions.

In 1948, Cronbach produced two of the most influential papers of psychological methodology: the "Alpha" paper (Cronbach 1951) and *The Two Disciplines of Scientific Psychology* (Cronbach 1957), in which he discussed the divergence between the fields of experimental and correlational psychology. His contributions to measurement issues and psychological testing were of central importance to psychology in general and to educational psychology in particular. The *Essentials of Psychological Testing* (Cronbach 1949) can be considered as one of the most influential contributions to the understanding of testing of the twentieth century.

Basically, the same holds true with regard to Cronbach's contributions to educational psychology, which consisted in finding a better explanation for learning in response to instruction. In 1954, Cronbach published a textbook on *Educational Psychology* in which he provides a holistic picture of learning in response to instruction (Cronbach 1954). Remarkably, it was at the zenith of neo-behaviorism when Cronbach began focusing on education as a central component of socialization as well as on maturation and development, personality and motivation, the acquisition of skills, ideas, images and attitudes, meaningful learning, emotional learning, and the assessment of achievement in schools. His central research question was the comprehension of person-situation interactions in instructional settings. Accordingly, he focused particularly on how different learners interact with the conditions and situational demands of instructional treatments. In the 1950s, Cronbach challenged instructional psychology to find the instructional treatment to which each individual can most easily adapt (Cronbach 1957). Consequently, his subsequent instructional research – especially his collaboration with Richard Snow – focused on matching instructional methods (or treatments) with students' aptitudes (Cronbach and Snow 1977).

Closely related to his interests in testing and instruction was Cronbach's development of an innovative framework for evaluation design, implementation, and analysis. In this context, he suggested the use of extensive field studies to produce useful narratives for teaching and learning.

Contributions to the Field of Learning

As his seminal book on educational psychology from 1954 shows, Cronbach focused mainly on *student learning in response to instruction.* In contrast to the dominating behaviorist view of the 1950s, Cronbach advocated a holistic view of human learning, and consequently he also included socialization and personalization (discussed in terms of biological maturation and development) as preconditions of learning. Furthermore, he placed great emphasis on motivational aspects of learning. He also discussed learning transfer, the completion of comprehension and thinking, and learning as participation as well as the acquisition of knowledge and attitudes and emotional learning. Reading his book on educational psychology, one has the impression of being transported into modern cognitive psychology on learning. It is simply one of the best books on educational psychology of all time.

However, maybe Crombach's most important contribution to the field of learning and education was his introduction of the theoretical concept of "aptitude–treatment interaction" (ATI) to educational psychology in the 1950s. This theory proposes that learning can be optimized when instructional methods are exactly matched to the aptitudes and styles of the individual learner. It aims at helping students capitalize on their strengths and compensate their weaknesses in learning. At the beginning of his research on this topic, Cronbach was looking for particular "aptitudes" of students that could affect their "responses" to an instructional treatment. Later in the 1970s, Cronbach focused increasingly on cognitive processes and their interactions with differently structured instruction. Based on several studies, Cronbach (1977) concluded that learning outcomes are better when the instructor's presentation adapts to the student's aptitude and personality. In terms of variance and regression analysis, the central objective of this early ► ATI research was to find empirical evidence for regression slopes that differ from treatment to treatment. ATI research was very prominent in the 1970s – not only in the United States but also in Europe (see, e.g., Flammer 1975; Seel 1979).

In his ATI research, Cronbach collaborated closely with Richard Snow (Cronbach and Snow 1977), who continued this research in the 1980s with a stronger emphasis on integrating individual differences in learning and cognition into the design of adaptive instruction (Snow 1980). Later he expanded the underlying information processing model of learning by introducing cognitive-conative-affective intersections. The objective was to integrate more realistic aspects of mental life, such as mood, emotion, impulse, desire, volition, and purposive striving into instructional models.

The collaboration between Cronbach and Snow set the stage for *learning orientation research*, which attempts to reveal the dominant power of emotions and intentions on the guidance and management of cognitive processes. In its basic understanding of the structure and nature of the complex relationships between learning orientations and interactions, this line of research can easily be traced back to Cronbach's original hypothesis that we should find the treatment to which each individual can most easily adapt. Although the ATI concept disappeared gradually as a research topic after the 1980s, the idea of matching abilities, instruction, and assessment is still at the core of instructional research today – ATI is the "sleeping giant" of learning orientation research (Sternberg 1996).

Cross-References

- ► Adaptive Instruction System(s) and Learning
- ► Adaptive Learning Through Variation and Selection
- ► Aptitude–Treatment Interaction

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Cross Talk Between Stored Memories

If synapses are shared by different stored memories, the retrieval of one particular memory can be contaminated by the undesired recall of other memories. Typically, synapses are shared if memory and query patterns are distributed; i.e., each pattern contains many active neurons. The strength of cross talk will increase with the number of stored patterns.

Cross-Cultural Approaches to Learning and Studying

► Cross-Cultural Learning Styles

Cross-Cultural Factors in Learning and Motivation

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Synonyms

Cultural factors in learning and motivation; Culture and learning and motivation

Definition

This term concerns those factors that differ across cultures which appear to have a significant influence upon students' orientation to learning and their subsequent educational achievement.

Theoretical Background

While there has long been interest in learning from other nations' educational practices, it was the advent of increasingly sophisticated test procedures and programs that could compare educational standards across countries, together with greater opportunity to observe and report upon overseas practices, that sparked huge political and mass media interest in cross-cultural factors underpinning educational achievement. Highly influential testing series include the Trends in International Mathematics and Science Study (TIMSS), examining mathematics and science achievements of children at approximately the 4th and 8th grade in many countries around the world; the Progress in International Reading Literacy Study (PIRLS), a comparable program in the field of literacy and reading; and the Program for International Student Assessment (PISA) in which standardized assessment has been administered to 15-year-olds in schools in more than 60 countries over a period of 10 years. Although PISA has tended to require the demonstration of more analytical and inferential skills than the more traditional TIMSS measures, the global pecking order has been relatively similar from one program to another.

Interest in these test programs grew to a peak in the 1990s when Western concerns were prompted by the differing academic performance of the leading industrial nations. In both mathematics and science, the two disciplines most widely compared, Asian countries consistently maintained a strong advantage. Between 1995 and 2003, for example, the five strongest nations were, for 8th grade mathematics: Singapore, Hong Kong, Korea, Taiwan, and Japan. For 8th grade science, a similar profile emerged: Taiwan, Singapore, Japan, Korea, and Hong Kong. In part, Western angst over test scores reflected uncertainties about economic competitiveness, as much as national pride, and the comparatively poor test scores of the US and Western European nations became associated with the increasing economic challenge posed by the Tiger economies of South East Asia.

The key question of the time was what factors explained the success of the Asian countries, and how might educational practices be modified in order to compete more effectively? In an influential report written for the UK Government, Reynolds and Farrell (1996) sought to explain the relatively strong performance of Pacific Rim countries. Four categories were identified consisting of cultural, systemic, school, and classroom factors. Unsurprisingly, policymakers latched onto those elements that appeared to be most susceptible to influence. Thus, their principal focus was upon pedagogy, in particular, a belief that it would be advantageous to introduce Asian and East European whole-class interactive teaching methods.

There is an obvious flaw in the suggestion that countries can raise achievement levels by introducing the pedagogic practices of high-scoring nations. Crucially, it would need to be shown that such practices are indeed the cause of such success. Whole-class teaching approaches are evidenced throughout the world and thus it would seem to be rather disingenuous to relate these only to high-scoring countries. Those advocating such an approach would need to explain why such practices have not proven successful in countries that have scored poorly. More detailed reflection suggests that it is not specific pedagogies that most explain high levels of national educational achievement but, rather, influential cultural factors that result in high levels of student motivation and engagement.

There has been a long tradition of cross-cultural research comparing children's development and socialization practices in Western and Eastern nations (e.g., Bronfenbrenner 1970; Stevenson and Stigler 1992). In a comparative study of educational motivation and engagement in sites in the UK, USA, and Russia, for example, Elliott et al. (2005) noted significant attitudinal and behavioral differences between Russian children, on the one hand, and UK and US students, on the other. These, it was argued, were products of long-standing historical practices and sociocultural understandings that operated across multiple levels of each society.

Key factors that appeared to explain the much greater commitment, work rate, and academic performance of the Russian children were:

1. General satisfaction, in the UK and US contexts, with lower educational work rates and levels of

academic achievement. This operated, not merely within the classroom, or even the school, but was also reflected by parental views and those of the wider communities from which the students originated. In contrast, Russian classrooms were traditionally seen by members of that society as a setting for hard work and maximum engagement, and there were widely agreed understandings that arduous study would also be undertaken after school hours.

2. Powerful peer influences that maximized student commitment. In contrast, in the USA and UK, peer influences appeared to undermine academic engagement and achievement. While effortless success in the classroom was generally acceptable in these latter contexts, it was often considered to be socially undesirable to display heightened interest in, or commitment to, one's studies. Allied to these social constraints were significant differences between the Russian and the Western children in respect of general classroom behavior and acceptance of teacher authority. These differences were similarly found in other contemporary cross-cultural investigations involving these countries.
3. A strong belief in the importance of education as a vehicle for personal improvement. To be an educated ("cultured") person was to be someone who was generally respected and admired. Thus, whatever one's abilities and goals, education was seen as being an important means of self-improvement. In the USA and UK, however, education is widely perceived in highly instrumental terms. While this, in itself, did not appear to be a motivational problem for those who believed that education could help them achieve their goals, such an orientation proved to be highly problematic for a significantly high proportion of underachievers who believed that they could never achieve such success.

Such a list maps closely onto those cultural factors that have been widely identified in the literature to explain the high levels of educational performance of South East Asian students (i.e., those from cultures primarily underpinned by the Confucian tradition) (Stevenson and Stigler 1992). Key amongst these are

1. Highly positive attitudes to learning and scholarship.
2. Very high standards and expectations in relation to educational achievement.
3. A powerful and influential level of family support. With this comes recognition that family hardship may be a necessary price to pay to achieve the highest levels of success. Parental obligation involves ensuring that their children learn well. In turn, children feel obligation to honor their parents' sacrifice by means of their academic achievement.
4. A belief in discipline and the importance of demonstrating effort. Traditional virtues include diligence, endurance of hardship, humility, concentration, and perseverance. These tend to persist even when families relocate to Western societies.
5. A strong sense of group identity in which the desires of the individual are subordinated to the needs of the class group.
6. A supportive pro-learning peer culture and the employment of high-achieving peers as important role models.
7. Respect for the authority and knowledge of parents and teachers.
8. Recognition that education is often a demanding and arduous process and does not need to always be fun or intrinsically appealing.

Important Scientific Research and Open Questions

Despite pride in their international standing, several nations scoring highly on international tests are now questioning whether their traditional values and approaches adequately equip their students to thrive in a global marketplace. However, it is recognized that the introduction of reforms brings associated risks because many of the personal characteristics that are deemed to be valuable for economic success have the potential to threaten traditional relationships and power structures. An interesting dilemma is whether it is possible, in such societies, to maintain the highly disciplined and focused educational orientation of young people while simultaneously increasing their capacity for autonomy, creativity, risk-taking, independence, spontaneity, problem-solving, assertiveness, and perhaps most controversially, their willingness to question and challenge.

However, this may be a moot issue as powerful social and economic forces are not easily controlled by government agencies. A breaking away from traditional attachments and identities, a strong emphasis upon individualism, and the seeming inability of existing institutions to guide young people, appear to be features of all late-modern or postmodern societies (Inglehart and Welzel 2005). Thus, a tradition of deference to adult authority, a strong emphasis upon self-discipline, a readiness to forego social and leisure pursuits in favor of narrow academic success, and a willingness to engage with unappealing academic material – factors all highly associated with high-scoring countries – may all ultimately be undermined by globalizing influences, irrespective of any national desire or legislative action.

Such phenomena were evidenced in the post-Soviet Russian educational context of the 1990s (Elliott and Tudge 2007). As Russian students became increasingly aware of their need to function in a very different society there were seismic shifts in their value systems toward a more Western outlook in which a heavy emphasis upon individualism and instrumentalism became apparent and ready acceptance of adult authority figures declined. Education was no longer seen as principally a means for self-development but, rather, as a route to a financially secure career. Whether this will ultimately result in reduced levels of motivation and engagement from a new, significantly sized, underclass is currently unclear.

Such concerns extend far beyond high-achieving South East Asian and post-Soviet contexts, as orientations reflecting Western globalizing influence appear to be increasingly evident in young people around the world. An important issue for future research, therefore, is to determine how such forces will differentially affect children's academic motivations and behaviors in these very different societies, and how, in each, the particular strengths and contributions of existing cultural understandings and practices can be secured and maintained.

Cross-References

► Motivation and Learning
► Motivation to Learn
► Motivational Variables in Learning
► Social Learning
► Socio-emotional Aspects of Learning

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Cross-Cultural Issues in Music Education

► Multicultural Issues in Music Instruction and Learning

Cross-Cultural Learning Approaches

► Cross-Cultural Learning Styles

Cross-Cultural Learning Styles

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Synonyms

Cross-cultural approaches to learning and studying; Cross-cultural learning approaches; Cross-cultural learning types

Definition

Cross-cultural learning styles refer to variations in the cognitive, affective, and physiological traits that are relatively stable, self-consistent, and characteristic indicators of how learners from different cultures perceive, interact with, and respond to the learning environment, including, but not limited to, the processing of information. In a more applied manner, cross-cultural learning styles can also be referred to as the degree to which the concept that individuals differ in regard to what mode of instruction or study is most effective for them varies across cultures.

Theoretical Background

The notion that culture has an all-pervading influence on all aspects of human life has led to an inquiry into its relationship with learning styles over the past three decades. The discourse on *cross-cultural learning styles* is deeply rooted in the larger topics of cognitive style and learning style. *Cognitive styles* are usually referred to as self-consistencies in processing information, solving problems, and making decisions that develop in characteristic and habitual ways around personality trends. The term *learning style* is both broader and narrower than *cognitive style* at the same time. On the one hand, it is narrower as its application is specifically limited to the context of a learning environment. On the other hand, it is broader as it goes beyond the cognitive by including affective and physiological behaviors. Wide parts of the extant literature still use the terms synonymously thereby creating confusion and incoherence. Some of the better known conceptualizations of learning styles are Marton and Saljö's *deep* vs. *surface* learning dichotomy, and Kolb's *Learning Style Inventory* (Apfelthaler et al. 2007). In the decades after their introduction, a plethora of alternative conceptualizations and instruments whose psychometric properties vary greatly (Coffield et al. 2004) have been developed. Most notable, among those, are the *Learning and Studying Questionnaire (LSQ)*, the *Revised Study Process Questionnaire (R-SPQ)*, the *Approaches and Study Skills Inventory for Students (ASSIST)*, the *Revised Approaches to Studying Inventory (RASI)*, the *Learning Styles Questionnaire (LSQ)*, the *Index of Learning Styles (ILS)*, the *Study Process Questionnaire (SPQ)*, the *Inventory of Learning Styles (ILS)*, or the *Approaches to Studying Inventory (ASI)* (Apfelthaler et al. 2007). Unfortunately, only very few of these instruments have been tested or used in more than one cultural environment. Therefore, despite decades of research on learning styles, and a general agreement that learning styles may vary from one culture to another (Richardson 1994), our knowledge of the relationship between cross-cultural differences and learning styles is still rather limited in its scope and its results.

Important Scientific Research and Open Questions

The majority of the existing research on learning styles comes from only a limited number of countries leaving available instruments largely untested in cross-cultural settings. By and large, the research on culture's impact on learning styles falls into one of two categories – studies of the learning behavior of students in certain national cultures, and comparative studies. Among the first group, a sizable number of studies have been conducted on learners in the Anglo-Saxon cultures of Australia, the United Kingdom, and the United States of America. Also, with the number of students seeking a degree outside of their home country on the rise, several studies have been carried out on populations of students studying in foreign host countries, most notably on Asian students in English-speaking countries. In the second group of studies, we find a number of comparative studies focusing on direct comparisons between two or more cultures, as well as a smaller number of studies on the *multicultural classroom*. Unfortunately, as the existing research is far from not only a consensus about learning styles instruments, but also concerning the measurement of culture, the results of studies on culture's influence on learning styles are hardly comparable and largely inconclusive. Some studies confirm the influence of culture on learning styles and see, for instance, a culture-biased distribution of different types of learners across cultures, while other studies do not. Some authors even attribute greater explanatory power to other factors such as discipline, gender, or institutional factors when it comes to variations in learning styles. Similarly, common national cultural stereotypes such as, for instance, the Asian learner as rote-learner have both been confirmed and challenged by existing research on the topic (Watkins and Biggs 1996).

What is surprising is that in the entire literature on culture's implications for learning styles, there are only very few references to the vast amount of existing publications on cross-cultural differences that have otherwise attracted considerable attention, such as the works of Dutch researcher Geert Hofstede (e.g., Hofstede 1986). According to Hofstede, cultures vary across four dimensions that he calls *power distance*, *individualism*, *uncertainty avoidance*, and *masculinity*. In some of his earlier works, Hofstede made assumptions concerning the consequences of these dimensions for the learning behavior of students, including differences in profiles of cognitive abilities between the populations from which teachers and students are drawn and differences in expected patterns of teacher/student and student/student interactions. Based on his own research in 40 different countries, Hofstede predicts that students from certain Asian countries that score low on individualism and high on power distance, will have a strong preference for traditional student–teacher relationships that are based on hierarchy, respect, harmony, and formal instruction (Hofstede 1986). It is somewhat surprising that, except for a few notable recent contributions (e.g., Apfelthaler et al. 2007; Yamazaki 2005), learning styles research has not embraced Hofstede's work on cultural differences to a greater extent. Based on the existing literature on cross-cultural learning styles, a number of open questions and directions for future research can be identified. These include (1) the testing of existing learning styles instruments in cultures other than those in which they have been developed and, if necessary, their revision; (2) the development and test of a conceptual model of how culture influences learning styles; and (3) studies comparing two or more cultures using those learning styles instruments that show strong psychometric properties across different cultures.

Cross-References

- ► Cross-Cultural Factors in Learning and Motivation
- ► Cross-Cultural Training
- ► Culture of Learning
- ► Learning Styles
- ► Social Interaction Learning Styles

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Cross-Cultural Learning Types

► Cross-Cultural Learning Styles

Cross-cultural Training

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Synonyms

Intercultural training

Definition

Training is one of the methods of interactive education, specifically organized short-term group work, and based on the assumption that learners derive knowledge, skills, and competencies from personal – direct or simulated – experience. Metaphorically, training as a method can be described as a process of intense socialization, and in the case of cross-cultural training – intense *enculturation* (the realization an individual achieves about his own culture) and intense *acculturation* (the realization an individual achieves about a different culture). This relatively new field represents an interdisciplinary focus of cultural anthropology, cross-cultural psychology, sociology, sociolinguistics, intercultural communication, and multicultural education (Bennett et al. 2004).

Diverse programs of cross-cultural training are focused on direct interaction with other cultures and are designed to teach individuals to cope with situations of cultural variety, help them effectively deal with the inevitable stress that accompanies the cross-cultural experience, and be efficient in a multicultural environment. On the macro-level there are two main aims of cross-cultural training: (1) to bring about change in a social or cultural situation such as decreasing racism, chauvinism, and other forms of prejudice and discrimination existing in society, and (2) to resolve conflicts and promote more harmonious intercultural relations (Paige 1996).

Theoretical Background

Any program of cross-cultural training is trying to answer the question "How?": how an individual can establish interpersonal contact with other cultures, how he/she can acquire its values, norms, role structure, etc. This kind of training is supposed to cause a change in the learner's attitudes by developing sensitivity to intercultural differences and cross-cultural competence.

Even though any cross-cultural training aims to develop or improve the awareness, emotions, and behavior of trainees, the program itself might put different emphasis on the particular field where key results need to be achieved – cognitive, emotional, or behavioral. The cognitive approach focuses on giving students information about cultures and cultural differences and helps learners to understand how stereotypes and prejudice affect their interaction with members of other cultures. Therefore, its objectives are grounded in knowledge and social representations. The emotional approach focuses on transforming attitudes related to intercultural interaction by changing feelings toward "others" (from prejudice to tolerance), and teaches learners how to manage emotional reactions (such as anxiety, fear, or anger) during contact with other cultures. The behavioral approach is designed to develop skills which are necessary for effective interaction with other cultures (Bhawuk and Brislin 2000).

Regardless of the methodological approach chosen, cross-cultural training should be built on the principle of cultural universalism. Any case where an intercultural trainer suggests some customs, values, and norms of any culture are "right" or "wrong" could draw the student back to the ethnocentric position. On the other hand, extreme cultural relativism could be counterproductive as it may call into question the very possibility of successful interaction and understanding between different cultures.

Implementing the principle of cultural universalism requires a high level of professionalism from the *cross-cultural trainer* at every stage of the program's design – from the methodological development to assessing its effectiveness. The model of an intercultural trainer's competences by M. Paige consists of four main categories: knowledge, skills, personal attributes, and ethics (Paige 1996). An intercultural trainer should possess the following skills: an ability to determine participants needs, to design the training course (set the goals, objectives, content, and selection of methods), and to implement and assess the program. The trainer also needs to have deep cross-cultural knowledge, cross-cultural self-awareness, familiarity with the developmental models of ethnic identity, an understanding of the concept of culture shock, adaptation and acculturation, as well as an intercultural education in general. Ideally, he/she should be a mediator between cultures. According to various sources, the following personality traits, values, and attitudes are required: tolerance to uncertainty, flexibility in cognitive style and behavior, possession of a clear idea of his/her own ethnic identity and universal values, openness to a variety of views, interest in others, empathy, and the tendency to lean toward cooperation during conflict. Finally, an effective intercultural trainer strictly obeys ethical and "do no harm" principles.

Important Scientific Research and Open Questions

The end of the World War II marks the beginning of the cross-cultural training field, when Edward T. Hall drew attention to the lack of adequate training materials. This continued to be the case until the mid-1970s when the first handbooks on intercultural communication were published. The beginning of research and experimentation produced many of the training techniques commonly used today. Familiar methods such as role plays, critical incidents, case studies, and simulations provided a point of entry for engaging in the research and theory building that would produce strategies to prepare people to function interculturally. In the late 1980s, cross-cultural training became widely demanded, therefore programs appeared that were more sophisticated and targeted to specific audiences.

As the importance of customizing approaches and activities were taken into account for an extensive range of cultural variations, it also gave rise to new models (Pusch 2004).

A typical training program combines didactic and experiential methods with either a culture-general or a culture-specific approach (Cushner and Brislin 1997). Each type works with a specific set of methods: (a) *Experiential culture-general* training focuses on a trainees' cultural self-awareness (the model of cultural identity). Such an approach is implemented in cross-cultural workshops by exploring how trainees' own socialization has influenced their perception, attitudes, stereotypes, and behavior. Another method is culture-general simulation which is usually constructed as a "meeting of two cultures" and gives trainees an opportunity to gain an experience of belonging to an imaginary culture with its norms, values, and behaviors that are different from the trainees' native ones. (b) *Experiential culture-specific* training uses culture-specific simulations and role plays, which attempt to help trainees learn how to interact effectively with members of a specific group. *Cultural assimilators* are collections of critical incidents that relate to the experiences of people from two or more cultures who face the problem of resolving some task. Another powerful program is intergroup dialogs, which could be used in situations of disagreement and conflict between different ethnic communities and provide an opportunity to make a mutual step to find a common ground. In many cases, the lack of understanding between people from different cultures occurs on the level of interpretation and has no basis on a behavioral level. Therefore attributive culture-specific training focuses on the way people from different cultures interpret the reasons for different behavior. Attributive training helps to make expectations about the possible behavior of an individual from different cultures more accurate and contributes to the development of isomorphic attributions. (c) *Didactic culture-general* training is mainly based on cognitive approaches such as lectures, films, videos, and culture-general assimilators. (d) *Didactic culture-specific* training provides opportunities for trainees to gain information about specific cultures. Training methods include culture-specific briefings, culture-specific assimilators, and readings.

The most popular programs of cross-cultural training were verified in the 1990s (Bhawuk and Brislin 2000). Researchers have noted the positive effect of commonly used programs in following five phenomena: the personal growth of trainees, a positive change in the perception of other groups and relationships with representatives, adaptation, and achievement in work and study. Positive effects of the cross-cultural training have also been claimed in some recent research for a wide variety of measures, such as subjective experience of the training, interpersonal relations, intercultural sensitivity, and intercultural adjustment (Van de Vijver and Breugelmans 2008).

However, the problem of assessing cross-cultural effectiveness is still very far from being solved. Up to today, the effectiveness of very few procedures has been explicitly demonstrated. For most training programs, validity data remains absent, which means there are no methodological foundations for many cross-cultural procedures (Van de Vijver and Breugelmans 2008). The main reasons for that are: (a) problems with identifying or designing adequate tools to assess cross-cultural competence; (b) problems with establishing causality in studies of cross-cultural research in general; (c) problems of obtaining adequate samples due to the specificity of the subjects; and (d) problems relating to interpreting the results of a controlled experiment such as training.

Despite identified problems, demand for cross-cultural training continues to grow, and its methods are being adapted and implemented for many specific audiences in education, health care, hostage negotiation, dispute resolution, law enforcement, the media, politics, and even cyberspace (Pusch 2004). In dealing with cross-cultural training it is important to take into consideration that according to many experts in the field, "intercultural training is both an art, which is appropriately passed on by experienced teachers, and a science, which is appropriately winnowed by empirical research" (Bennett et al. 2004, p. 8).

Cross-References

► Competency-Based Learning
► Cross-Cultural Factors in Learning and Motivation
► Cross-Cultural Learning Styles
► Developing Cross-cultural Competence
► Enculturation and Acculturation
► Learning and Training: Activity Approach
► Social Influence and the Emergence of Cultural Norms

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Cross-Disciplinary Education

► Integrated, Multidisciplinary, and Technology-Enhanced Science Education

Cross-Disciplinary Learning

Cross-disciplinary learning refers to learning activities that are related with a subject outside the scope of a discipline without any integration from other disciplines. The study of genetics, for example, crosses several disciplines, including biology, chemistry (e.g., the molecular structure of DNA), and environmental science (e.g., conservation genetics). Additionally, facets of genetics also overlap with mathematics, social studies, and health studies. Cross-disciplinarity means that topics are studied by applying methodologies of unrelated disciplines.

Cross-disciplinarity differs from interdisciplinarity: In the case of cross-disciplinarity, the boundaries of disciplines are crossed but no techniques or ideals, while interdisciplinarity blends the practices and assumptions of each discipline involved.

While cross-disciplinarity and interdisciplinarity are different, multidisciplinarity is closely related with cross-disciplinarity. In multidisciplinarity also, there is no transfer of methodologies between the disciplines. In contrast to cross-disciplinarity, multidisciplinarity includes more than one discipline outside a discipline of interest.

Cross-Disciplinary Research on Learning

► Multidisciplinary Research on Learning

Cross-Linguistic Influence and Transfer of Learning

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Synonyms

Cross-linguistic transfer; L1-L2 facilitation/inhibition; Language transfer; Linguistic interference

Definition

Cross-linguistic influence (CLI) is typically defined as the influence that knowledge of one language has on an individual's learning or use of another language. This influence can involve various aspects of language. For example, for a native speaker of Spanish who is learning English, CLI may lead to Spanish-sounding pronunciation when speaking English (e.g., pronouncing “zoo” like “soo”), Spanish word or sentence order when writing in English (e.g., writing “The car red is mine,” instead of “The red car is mine”), or comprehension of Spanish words that look or sound similar to English words (e.g., “turista” = “tourist”). CLI is related to transfer of learning: Transfer of learning involves the application of knowledge in novel situations, and CLI can be seen as one specific type of transfer of learning restricted to language-related knowledge being applied in situations involving the use of another language.

Theoretical Background

CLI has been a central topic in research and theory on second language acquisition (SLA). In a seminal publication, Odlin (1989) traced the origin of scholarly work on CLI back to nineteenth century debate about the effects of language contact and mixing on language classification and change, for example in the study of pidgins and creoles. In the twentieth century, influential early publications on CLI include Weinreich's (1953) examination of CLI in the phonetic, grammatical, and lexical systems of bilinguals, and Lado's (1957) manual on contrastive analysis, which included claims that a systematic comparison of two languages could be used to predict where second language learning difficulties would occur. In the 1960s and 1970s, SLA research expanded in scope and emphasis was placed on factors other than CLI that influence second language learning, such as factors that influence first language learning. However, CLI continues to receive a great deal of research attention (e.g., in influential journals such as *Studies in Second Language Acquisition*, *Language Learning*, and *Applied Linguistics*), and the body of scholarly work on this phenomenon shows in an increasingly diverse collection of contexts the consistency with which CLI plays a role in SLA.

In the extensive body of literature on CLI, connections between CLI and transfer of learning are apparent. Odlin (1989) pointed out that CLI is seen by many SLA scholars as a construct that was appropriated from psychology research and theory on transfer of learning in the mid-twentieth century. Furthermore, SLA scholars have suggested that CLI involves more general cognitive processes: Ringbom (1986), for example, suggested that it is beneficial to view the source of CLI (e.g., a first language) as only part of the knowledge base an individual has that can be transferred, while Faerch and Kasper (1986) suggested that CLI can be seen as a case of a learner extending existing knowledge to new contexts. Also, in a more recent overview of scholarly work on CLI, Jarvis and Pavlenko (2008) argued that CLI involves not only traditional categories of language (e.g., phonology, syntax) but also higher-level cognitive concepts (e.g., the way objects are categorized).

The connection between CLI and transfer of learning is also apparent in overlap in factors that influence CLI and factors that influence transfer of learning. One of the main factors linked to CLI is perceived cross-linguistic similarity: CLI is more likely when an individual perceives similarity between two languages, and less likely when an individual perceives difference between two languages. Along the same lines, individuals' perceptions of similarity and difference (i.e., between tasks and contexts) are seen as a major influence on transfer of learning. Other factors that have been linked to both CLI and transfer of learning are (a) knowledge base (e.g., language proficiency), (b) amount and type of practice, (c) attitudes and motivation, and (d) sociocultural context.

In addition, although transfer of learning is a broader construct than CLI, transfer of learning research has, like CLI research, examined language-related knowledge, for example vocabulary, grammar, and pronunciation, as well as reading and writing skills and strategies. For instance, in an investigation of the development of reading skills among elementary school students, Martin-Chang et al. (2007) examined techniques for learning new words; this study explored whether students' knowledge of new words learned through different techniques (e.g., individually on flashcards; in the context of a story) transferred to novel reading tasks. Similarly, Williams et al. (2005) studied transfer of learning from a reading comprehension instruction program; this study examined whether training students to use strategies to analyze the structure of a text had any influence on their subsequent performance reading other texts. These and other transfer of learning studies that investigated individuals' first language knowledge are different from CLI research that by definition examines the interface of two languages; however, such transfer of learning research does examine transfer of language-related knowledge, which is a characteristic it shares with CLI research.

Finally, although CLI research might be seen as focusing on relatively deep learning (i.e., an individual's first language, which has typically been learned over an extensive period of time) compared to transfer of learning research (i.e., which might involve studying transfer after only short periods of training), CLI research also can involve more shallow learning. CLI has been viewed specifically as the influence of an individual's first language on second language learning and use; however, current definitions of CLI tend to be broader and also include the influence of a second language on the learning and use of a third language (or a fourth language, etc.), as well as the influence of a second language on first language use. Since individuals learn second languages in a variety of ways, there is tremendous variety in the depth of learning associated with a second language. This variation means that the source of CLI may not always be as deeply learned as a first language system. For example, Kecskes and Papp (2000) examined CLI among secondary school students whose first language was Hungarian and who were studying English, French, or Russian as a second language; the findings showed that some types of second language instruction had an influence on the students' use of their first language (e.g., use of subordinate clauses when writing in Hungarian).

Important Scientific Research and Open Questions

From a CLI perspective, the connection between CLI and transfer of learning raises important questions. First, can theories related to transfer of learning help shed light on unanswered questions about CLI? For instance, one of the central unanswered questions about CLI is how individuals' perceptions of similarity between languages are triggered. From a transfer of learning perspective, theories have been offered for how the human brain identifies similarities in incoming information, for example by being hardwired with a kind of harmonic structure that facilitates recognition of similar relationships in different situations (e.g., relationships between notes in a song that one is familiar with but that is being played in a key higher or lower than before) (Haskell 2001). Such accounts may also be relevant to CLI.

In addition, which findings from transfer of learning research that has involved language-related knowledge might apply to CLI? For example, Martin-Chang et al. (2007) found that elementary school students' transfer of first language word knowledge in first language use situations depended on the congruence between the learning technique and the kind of transfer task: Performance on a transfer task involving reading isolated words was more accurate if the words had been learned in isolation (i.e., on flash cards), and performance on a transfer task involving reading words in context was more accurate if the words had been learned in context (i.e., in a story). From a CLI perspective also, it is worth asking if the influence of first language word knowledge on second language learning and use would also be constrained by the congruence between learning tasks and transfer tasks. Similarly, Williams et al. (2005) found that training students to use several strategies to analyze the structure of a compare/contrast expository text had a positive influence on their subsequent performance with texts with a similar structure, but not with texts with a different structure. From a CLI perspective also, it is worth asking if the use of first language reading strategies to read second language texts would be constrained by similarity in genre between texts used in learning tasks and transfer tasks. Similar questions can be generated from the numerous other transfer of learning studies that have examined language-related knowledge.

Finally, it is important to ask if and how findings from other transfer of learning research (i.e., research that involved knowledge less directly related to language) may also be relevant to CLI. For example, transfer of learning research has focused on the influence of factors such as attitudes and motivation, and sociocultural context (Haskell 2001). SLA researchers have pointed to such factors as relevant to CLI as well. A study by Kecskes and Papp (2000) examined CLI among secondary school students who spoke Hungarian as a first language and were studying English, French, or Russian as a second language, and CLI was reportedly influenced by learning contexts/tasks (i.e., CLI from second language learning to first language use varied with the kind of second language instruction students received) and student motivation. Both learning tasks/contexts and motivation were also highlighted as a potentially important nonlinguistic influence in Weinreich's (1953) influential study of CLI. Finally, the influence of sociocultural context is reflected in the way individuals may adjust their language use patterns – in a way that involves more or less CLI – depending on the perceived identity of the person with whom they are speaking (Jarvis and Pavlenko 2008). However, CLI research on these particular factors is limited. Relevant questions therefore include the following: How do motivation and sociocultural context influence CLI? Might CLI be more likely in some cases if an individual feels motivated to make use of existing first language knowledge and skills in second language use situations? Might CLI be more likely in some cases if an individual feels that the sociocultural context encourages the use of existing first language knowledge and skills?

Cross-References

- ► Language Acquisition and Development
- ► Second Language Learning
- ► Transfer of Learning

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Cross-Linguistic Transfer

► Cross-Linguistic Influence and Transfer of Learning

Crossmodal Facilitation

► Intersensory Facilitation

Cross-Modal Learning

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Synonyms

Multimodal learning

Definition

Cross-modal learning refers to any kind of learning that involves information obtained from more than one modality. In the literature the term modality typically refers to a sensory modality, also known as stimulus modality. A stimulus modality provides information obtained from a particular sensorial input, for example, visual, auditory, olfactory, or kinesthetic information. Examples from artificial cognitive systems ("robots") include also information about detected range (by sonar or laser range finders), movement (by odometry sensors), or motor state (by proprioceptive sensors). We adopt here a notion of modality that includes both sensorial data, and further interpretations of that data within the modality. For example, from a pair of (depth-calibrated) images, a cloud of points in 3-dimensional space can be computed. We obtain both types of data (the image data, and the 3D points) from the same visual sensor. At the same time, they differ in what information they provide. We consider information sources derived from sensorial data as derived modalities that by themselves can be involved again in cross-modal learning.

Theoretical Background

We distinguish different types of cross-modal learning. The distinction is based on how the learnt model (interpretation) depends on the data from several modalities, and to what degree the model integrates information from these modalities.

In weakly coupled cross-modal learning, models are built within individual modalities. There is only an inflow of information from other modalities into a modality that is learning. This modality uses the information as a label or reinforcement signal to supervise its internal learning process. Inference based on the learned models can be done on the basis of a single modality, or the output of several modalities can be combined to achieve better performance or robustness. One example of this is speech recognition. In situated dialogue, recognizing sequences of words in an audio signal can be greatly improved by information about the situated context (what is there to be seen, what is there to be done, what have we talked before), and through observation of the speaker. Context and observations aid disambiguation during processing of the auditory signal, possibly also correcting misheard words, or filling in (grammatically) missing words. For example, lip reading can greatly aid recognition. In a continuous learning process, successfully recognized lip poses can supervise learning of audio-based speech recognition ability. The other way round, correctly recognized audio input can provide labels to aid the learning of lip reading. This process of coupled supervision during learning is also known as co-learning. In the end we obtain two classifiers, one in each modality, that can be used individually, or they can be combined to further increase the success of speech recognition. This type of cross-modal learning is thus based on a weakly coupled interaction of data from different modalities, which is done on a rather high level of abstraction. In the case above we assumed that both modalities mutually drive the learning in the other one. This process can in principle be unidirectional. If the information in one modality is much more reliable, it can drive the learning in another modality.

In closely coupled cross-modal learning, learning processes are more intertwined. A model is learnt by combining information from different modalities into a common level of representation, and then using this level as a starting point to build a common cross-modal classifier or predictor. As a result, inference with the acquired model requires information coming from several modalities, and cannot be achieved within a single modality only. This approach is often used in sensorimotor learning. Here, low-level features from a visual modality and motor (or proprioceptive, or haptic) modalities are merged. Based on the obtained cross-modal features, higher-level sensorimotor concepts are learned. For example, from low-level visual features describing objects and low-level features parametrizing actions that could be performed, a model is learned that predicts what happens with a particular object if a particular action is applied (through classification or regression). Another example is when the feature vectors still reside in the individual modalities, but we construct several intermediate classifiers, which are no longer independent, and combine them. This requires a close-coupling of semi-synchronous learning processes, based on interconnected representations, and leading up to the formation of cross-modal concepts.

We can also identify a third type of cross-modal learning that is performed on a higher level of abstraction. Here, a model is acquired that connects modal conceptual structures from different modalities by learning associations between them. For example, let us suppose that we want to recognize a cup of coffee. A cup can be recognized visually. Yet, to recognize what is inside the cup we need another sense – smell. We need to combine information from both modalities to determine that there is a cup of coffee on the table and not a cup of a black tea. The learning of required concepts could be performed largely independently, in each modality individually. At some point though we need to learn to combine the concepts of the cup and the coffee into a concept of a "cup of coffee." The final representation therefore consists of representations from several modalities.

Cross-modal learning is related to principles of fusion of data from different sensors (Clark and Yuille 1990), also known as multisensory processing in natural cognitive systems (Stein and Meredith 1993). Different processes interact in a cognitive system to form a coherent interpretation of experience, based on the combination of information obtained through several modalities. The process of learning how to combine this information is a kind of cross-modal learning.

As already mentioned, we can consider the term modality in its wider sense. This includes derived modalities. In this case, the type of information that characterizes a modality is not attached directly to a sensor, but to a process which interprets the sensorial data. For example, suppose that we have a place recognition approach that is based on both visual images, and 3D point clouds representing geometrical structure. The images may be obtained using a camera. The 3D point clouds are obtained using a laser range finder, or, alternatively, both the images and the 3D data can be obtained using a stereo rig. In both cases we can conceive of the learning of representations of places as a kind of cross-modal learning, although in the second case we have one sensor only. In computer vision, it is very often favorable to extract several visual cues (such as color, texture, borders, shape, motion), and combine them in order to obtain better classifiers. We can look at the learning of such combined classifiers as at a kind of cross-modal learning as well.

The relevance of cross-modal learning is alike for natural and artificial cognitive systems (Christensen et al. 2010). Both continuously learn to extend their knowledge of acting in dynamic environments. The ability to connect possibly asynchronously developed models across different modalities provides an important basis for a grounded form of self-understanding. The possibility to interconnect and thus form an interpretation that is coherent across multiple modalities indicates what is known relative to some experience. Failure to do so may indicate a knowledge gap, and can function as a trigger for self-aware learning.

Important Scientific Research and Open Questions

There are arguments for learning to be based on association, and for learning to be mediated by a (developing) categorical system. Very often, the interconnectivity between modalities is mediated by categorical structure. Effectively this establishes a triadic relation between modalities. The conceptual structures in the modalities can be connected because they can be understood as related by virtue of their reference to a shared categorical ground. The arguments for this type of learning, based on the formation of a mediating categorical structure, arise from, for example, childhood cognitive development. In word learning it is shown that a purely associative, unmediated account ("child-as-data-analyst," Sloutsky (2003)) cannot appropriately account for categorical generalizations a child is able to make ("child-as-theorist," Waxman and Gelman (2009)). The use of mediating categories both helps generalization of sensory input beyond actual experience, and allows for representations to be ultimately grounded in, and influenced by, the embodiment of the system (Lakoff and Johnson 1999; Barsalou 1999; Glenberg 1997). On the other hand, in many cases the modalities interact on a much lower level, like in the case of sensorymotor learning. It is still an open question what roles do these different forms of learning play in specific types of cross-modal learning, whether in natural or artificial cognitive systems (Philipona et al. 2003).

A fundamental aspect of embodied cognition is that understanding is ultimately based in how a cognitive system experiences the world. Since the cross-modal learning is based on processing and relating information from several (sensory) modalities it may play an important role in bringing about grounded forms of cognitionde (de Sa and Ballard 1998).

We also have to address the terminological issues, since the terms related to cross-modal learning are not consistently used in the literature. Sometimes, the term cross-modal learning is used only to refer to strongly coupled types of cross-modal learning. Also, the term modality is sometimes used in its narrower sense, considering sensory modalities only. Here, we adopted the broader meaning of both terms. There is also another term in the literature that is often used to describe a similar phenomenon, the term multimodal learning. One meaning of this term refers to (human) learning based on different multimedia material involving different human senses that facilitate learning. The second meaning of this term is very close to the meaning of cross-modal learning as defined above. Sometimes this term relates to forms of weakly coupled cross-modal learning, while very often cross-modal and multimodal learning are used interchangeably with the same meaning (synonyms).

Cross-References

- ► Active Learning
- ► Adaptation and Learning
- ► Cognitive Models of Learning
- ► Cognitive Robotics
- ► Embodied Cognition
- ► Learning and Understanding

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Cross-Sectional Research

► Longitudinal Learning Research on Changes in Learning of University Students

Cross-Situational Learning

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Synonyms

Associative learning

Definition

Cross-situational learning is a technique for learning the meanings of words across multiple exposures, despite uncertainty as to the word's meaning on each individual exposure. The cross-situational learner encounters a word in a number of different situations, each of which provides a set of multiple candidate meanings; the learner determines the word's meaning by selecting from those meanings which reliably recur across situations. Cross-situational learning is less cognitively demanding than many other models of word learning, because it does not require a learner to unambiguously identify a word's meaning on a single exposure.

Theoretical Background

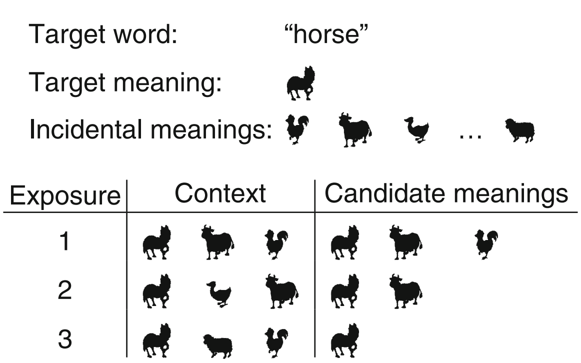
During language acquisition, children learn a lexicon containing many thousands of associations between words and their meanings, at the rate of around ten new words a day. Children accomplish this task rapidly and remarkably successfully, overcoming potentially unlimited uncertainty about the meaning of every new word they encounter, and identifying some aspects of word meaning after only a very few exposures through so-called fast mapping. Quine (1960) famously illustrated the problem of referential uncertainty through the story of an imaginary anthropologist working with a speaker of an unfamiliar language: when a rabbit runs past, the speaker shouts "gavagai," and the anthropologist tentatively notes that this new word means "rabbit." Quine's insight was to point out, however, that the anthropologist can never be sure that "gavagai" means "rabbit," no matter how many future clarificatory tests are carried out; it could, after all, have an infinite number of possible meanings of varying plausibility, including "animal," "white," "undetached rabbit parts," "dinner," or "it will rain."

Yet despite the philosophical problem of unlimited referential uncertainty, children clearly *do* learn large lexicons, and the focus of much research into word learning has been on providing explanations for this. The dominant approach has been to identify mechanisms which allow the learner to exclude from consideration many meanings which are theoretically possible but in reality spurious, thus reducing the level of referential uncertainty in the input to a more manageable level, and simplifying the task of determining the word's true meaning. A number of heuristics have been put forward: interpreting behavioral cues in order to identify the speaker's focus of attention; assuming that novel words are more likely to refer to whole objects rather than their parts or properties; building on existing knowledge about the meanings of other words and assuming that new words will have different meanings; making use of the syntactic context in which the new word is presented to infer aspects of its meaning (see Bloom 2000, for review). While quantifying the impact of such heuristics is problematic, it is clear that some referential uncertainty is likely to remain even after the application of many or all of them; the utility of cross-situational learning stems from the fact that it allows words to be learnt despite the existence of residual uncertainty.

Cross-situational learning works by amalgamating information about the meaning of a word from across the various different situations in which that word occurs. Each separate context in which the word is used yields a (possibly infinite) set of possible candidate meanings, which is potentially reduced through the application of word-learning heuristics such as those described above to a finite set of candidate meanings (including the true meaning); the same word uttered in a different context may of course yield a different set of candidate meanings. Candidate meaning sets from different contexts can be combined, enabling the learner to identify the most likely correct meaning, for instance, by identifying the meaning which lies at the intersection of the sets, as shown in Fig. 1. Although each exposure to a new word may provide a large number of possible meanings, and thus a large degree of referential uncertainty, successive exposures in different contexts will gradually reduce the uncertainty, eventually eliminating it completely by winnowing the set of possible meanings down to the true meaning alone.

This eliminative approach to cross-situational learning illustrated in Fig. 1, however, is vulnerable to failure in a number of real-world circumstances (see Gleitman et al. 2005, for discussion): In noisy situations where the intended meaning is not suggested by the environment, it will be sifted out of the set of possible meanings; in homonymous or polysemous situations where the word has more than one intended meaning (e.g., the English word “bank”), none of the intended meanings will appear in all exposures, and thus the set of possible meanings will be empty (i.e., situations in which “bank” is used as a verb denoting turning will probably not feature financial institutions in their set of likely meanings; likewise, situations in which it is used as a noun will not reliably feature the act of turning).

These vulnerabilities stem from the pure cross-situational learner maintaining the *maximal* amount of cross-situational information, namely, an accurate set of candidate meanings which always occur with the word. At the other end of the spectrum, a learner could make *minimal* use of cross-situational information by simply remembering a single one of the meanings suggested in a previous exposure, and maintaining this as their preferred meaning so long as it is also suggested by the current context. Between these two extremes lie an infinite number of potential cross-situational learning strategies, much more resilient to noise, yet less powerful than pure cross-situational learning (Blythe et al. 2010). In particular, a *frequentist* strategy, where learners track the frequency with which candidate meanings co-occur with the target word, appears to match well the data from experimental tests of cross-situational learning (Yu and Smith 2007; Smith et al. 2011).



Cross-Situational Learning. Fig. 1 Cross-situational learning. Each time the word *horse* is used, the context provides a different set of candidate meanings. Uncertainty about the meaning of the word is gradually reduced and finally eliminated through its appearance in multiple exposures, as candidate meanings which are not suggested by each context are eliminated from consideration

Important Scientific Research and Open Questions

Existing research into cross-situational learning can be grouped into two main approaches: formal computational and mathematical models examining the operationalization of cross-situational learning and its plausibility as a tool for language learning, and experimental work exploring the conditions under which humans use the different cross-situational learning strategies.

Siskind (1996) developed an early and influential computational implementation of cross-situational learning based on the eliminative process illustrated in Fig. 1, describing an algorithm which was capable of identifying word meanings after exposure to a synthesized corpus of utterances paired with both intended and spurious meanings. Siskind further demonstrated that his cross-situational learning procedures could be specified so that the algorithm could recover from errors originating from environmental noise and homonymy. More recent formal models (e.g., Yu et al. 2005) have successfully demonstrated that cross-situational learning can be used to infer the meanings of words from increasingly complex and realistic, though still small, corpora of natural language use. Mathematical models, meanwhile, have shown that cross-situational learning is viable not just with small corpora, but also scales up to the learning of large, human-size vocabularies within reasonable timescales (Blythe et al. 2010). Despite significant levels of referential uncertainty at each exposure, the relative learning speed disadvantage of cross-situational learning compared to an idealized fast-mapping learner is surprisingly small. There is, therefore, no necessary link between the ability to learn individual words rapidly and the ability to acquire large vocabularies.

A body of research has demonstrated that both adults and infants can effectively exploit cross-situational learning information when learning small numbers of words (e.g., Akhtar and Montague 1999; Yu and Smith 2007), using both naturalistic and more controlled (and therefore quantifiable) stimuli. The effectiveness of cross-situational learning in humans is affected by the degree of referential uncertainty: performance (in terms of number of words learnt) decreases as referential uncertainty increases. Furthermore, increasing referential uncertainty appears to change the mechanism by which cross-situational learning takes place, with increased referential uncertainty prompting a shift from a pure eliminative strategy to a less demanding, more nuanced, frequentist equivalent (Smith et al. 2011).

This recent emphasis on examining when alternative cross-situational strategies are employed by learners leads to a number of currently open questions. Increasing referential uncertainty naturally increases the time it takes to learn a lexicon, yet weaker forms of cross-situational learning (those which make less efficient use of cross-situational statistics) are disproportionately affected by increases in referential uncertainty than stronger forms.

At some point, therefore, increasing referential uncertainty will make a human-size lexicon impossible to learn by cross-situational learning in a reasonable timescale. Quantifying this critical point, however, is still problematic, not only because of the difficulties in accurately quantifying the referential uncertainty of naturalistic data, but also because the experimental evidence for when and how people shift learning strategies is currently rather minimal. Furthermore, existing research into different variants of cross-situational learning has primarily been carried out on adults, posing the question of whether children shift strategies in response to task demands in the same way as adults, or whether they even use the same cross-situational learning strategies at all.

Cross-References

► Associative Learning
► Embodied Cognition
► Heuristics and Problem Solving
► Matching
► Meaningful Verbal Learning

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Crosswise Research

► Longitudinal Learning Research on Changes in Learning of University Students

Crystallized Intelligence

Knowledge that includes general world knowledge, vocabulary, and reasoning. It is also used to refer to the ability to perform learned skills. This type of intelligence is often referred to as "crystallized" because this type of intelligence remains relatively permanent once it is acquired.

CS Processing

► Attention and Pavlovian Conditioning

Cue

► Cue Summation and Learning

Cue Summation and Learning

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Synonyms

Clue; Cue; Learning; Medium; Method; Multiple; Stimuli; Summation; Visual

Definition

The word *cue* refers to the information that helps to solve a problem. *Cue* is also referred to as *clue.* The word *summation* refers to the use of multiple methods (i.e., combination of visual, auditory, and words) to solve a problem. The word *learning* refers to knowledge or skills acquired through study or by being taught. The term *cue summation and learning* is used in the sciences of learning and cognition to designate a process of delivering and acquiring information by being taught via multiple methods delivering same message.

Theoretical Background

Cue summation is a type of information processing/human cognition/communication process that deals with learning and retention. In cue summation, cue contains multiple method of delivery containing same message in producing learning (Severin 1967b), i.e., visual presentation-printed word combination, picture-spoken word combination, video-printed word audio combination, video-spoken word combination, and printed word–spoken word combination. Cue summation theory predictions are as follows:

- Cue summation (multiple cues) should be superior to a single cue condition (Brashears et al. 2005).
  - For Example: I want to show picture of my car.
  - Cue summation example: Simultaneously, presenting the picture of my car (visual) + spoken words – This is my car (Aural). Both clues are related to each other.
  - Single Cue example: Presenting picture of my car (visual).
- Related cues presented visually with spoken words may be more effective in producing recognition than redundant cues presented visually with spoken words combination (Hartman 1961).
  - Nonrelevant cue example: Simultaneously presenting the picture of my car (visual) + spoken words – Look at this picture (Aural).
- Cue summation presented visually (words in print) would be superior to words presented audibly (words pronounced).
- Visual cues are more effective than words presented visually in producing paired-associate learning.
  - Words presented visually (example): Presenting the picture of my car with the words (This is my car) printed on the picture.
- Visual cues help to process and remember verbal information and vice versa.
- Use of both auditory and visual channels should increase recall and retention (Clark and Paivio 1991).
- Visual + word combination would be superior to a printed word + Aural word combination.

Important Scientific Research and Open Questions

The above predictions may not be generalized as they were derived under specific conditions. Such predictions may not be relevant under different conditions. For cue summation and learning learners' achievements may be influenced, but not limited to the following aspects of learning process:

Learning Content

The quality and the structure of the content provided to the learner may influence the learning process.

Memory

Learners' memory is divided into sensory, short-term, and long-term memory. The memory capacity to process and store information may vary individually, which may influence the success of a learning process (Miller 1956).

Learning Style

Learners' preferred method of learning varies widely based on personal aspects of learning.

Delivery Method

Learning content delivered using methods such as printed handouts, digital text, computer-based graphical presentation, face-to-face instruction, audio video–based instructions, and computer-based interactive applications may influence the learning process (Laurillard 2002).

Delivery Platform

The delivery may influence how learners are involved in the learning process (e.g., whether individuals work at their own pace or with a group, learning from home, learning on the move, learning via different technologies like computers and mobile phones).

Learning Motivation

Learning motivation can be defined as learners' action or behavior behind engaging in the learning process, which reflects on the success of the learning process.

Cross-References

► Audiovisual Learning
► Auto-associative Memory and Learning
► Communication Theory
► Human Cognition and Learning
► Information Process Theory
► Learning in Mixed Realities
► Mental Imagery and Learning
► Multiple Resource Theory
► Sensory Memory: Iconic and Echoic Memories
► Short-Term Memory and Learning

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Cued Recall

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Synonyms

Primed recall; Prompted recall

Definition

Cued recall refers to retrieving information from long-term memory using aids or cues. Cues can be external stimuli, such as words, sentences, incomplete pictures, letters within a word, and so on, as long as they have some kind of connection to the to-be-remembered (target) information. That connection might be a semantic or associative relationship, temporal co-occurrence of a cue and target, or the cue could actually be the target presented in an incomplete form. For example, recall of the target *TIGER* might be cued with *lion*, *A ____ has stripes*, an incomplete drawing of a tiger, or *TI___*. Cues can also be internal. For example, people may be asked to think about what they were thinking about, their mood, or the spatio-temporal context at the time that they encountered a target in an attempt to cue retrieval of it. Cued recall is often contrasted to *free recall*, which mainly refers to the process of retrieving information from long-term memory without the provision of any explicit cues. Along with *recognition* memory (discrimination of previously-encountered stimuli from novel ones), free recall and cued recall constitute the most common explicit tests of memory.

Theoretical Background

Most theories of cued recall posit that retrieval of target information can be achieved via two routes. The first is an efficient *direct* route, involving recollection or *ecphory* of the sought-for details. The second route to recall if the direct route fails involves a process of *generating* plausible candidates, and then attempting to *recognize* the target from amongst the candidates.

Support for the *generate–recognize* route to recall has been garnered from studies demonstrating that cues that were strongly associated to a target were more effective than cues that were not (e.g., Bahrick 1970). However, generate–recognize models were criticized in the early 1970s by Tulving and colleagues (e.g., Tulving and Thomson 1973). The main source of their criticism was the phenomenon of *recognition failure* of recallable words, which was demonstrated in an experiment involving four stages. First, weakly associated cue-target pairs were studied for a later memory test (e.g., *stripes–TIGER*). Next there was a phase intended to encourage generation of targets, during which participants produced any words that came to mind in response to strong associates of the targets (e.g., *lion)*. In a third *recognition* phase, there was an attempt to *recognize* targets from amongst the generated items, which was often unsuccessful. Finally, the weak cues that were presented with the targets during the initial study phase were presented again to cue recall of targets (e.g., *stripes–?*). Recognition failure of recallable words was revealed in that targets not recognized during the recognition phase of the experiment (phase-3) were often recalled later in the presence of weak cues (phase-4). In other words, *TIGER* might have been generated to *lion*, but not recognized as a target, even though it was successfully recalled in the final phase when cued with *stripes*. Recognition failure is problematic for generate–recognize theory because phase-4 recall was limited by two bottlenecks (i.e., the target had to be both generated and then recognized), whereas phase-3 recognition was only limited by one (i.e., the target item had already been "generated" during phase-2). Thus, if recall really involves successive stages of generation followed by recognition, then Tulving and Thomson reasoned that recognition failure of recallable words could not have occurred.

Tulving and Thomson (1973) argued, instead, that their results were explained by the *encoding specificity principle*. This principle asserts that the effectiveness of retrieval cues is largely determined by whether they were present at the time the target information was encoded (i.e., encoded specifically with it). Thus, recognition failure occurred in their experiment because the cues that were encoded specifically with the targets were not available during phase-3, whereas they were available during phase-4. Consequently, phase-4 recall was superior to phase-3 recognition.

The encoding specificity principle and related ideas such as *transfer appropriate processing* highlight the importance of matching the conditions of encoding and retrieval to elicit good cued-recall performance. Similarity between the conditions of encoding and retrieval was important because both external and internal retrieval cues are embedded in those conditions. Examples of external retrieval cues include environmental cues (e.g., the particular room in which target information was learned/retrieved) or the cue words that were presented along with target information, as in the Tulving and Thomson's (1973) experiments. However, retrieval cues are also embedded in internal contexts, such as the type of mood learners had or the type of processing that they engaged in during encoding (e.g., whether target information was processed for meaning versus in terms of how it sounded). In all these cases, if the encoding and retrieval conditions are matched, then the likelihood is increased that there will be retrieval cues available at test that were specifically encoded with the target information during learning, thus enhancing recall.

Important Scientific Research and Open Questions

Tulving and Thomson's (1973) important work on the encoding specificity principle demonstrated that not all cues are equally effective at retrieving target information from memory. Although it is generally accepted that cued recall is superior to free recall, exactly which aspects of cues that cause this superiority has been the source of considerable research. The encoding specificity principle states that cues encoded with the target information are the most effective, but are there *extralist* cues (cues not presented during encoding) that are effective for retrieval? By comparing free recall with recall aided with different types of cues, it is possible to answer this question. However, it is important to consider the fact that, when making this comparison, free recall is free only of externally provided cues, such as words, letters, or sentence stems. In free recall, people are likely to strategically prompt themselves with covert cues. For example, a professor attempting to remember who attended a recent meeting might covertly "walk around the department," generating colleagues' names from memory for the spatial location of their offices, and then attempting to recognize those names from the meeting. Hence, even so-called free recall is likely to be cued in some sense. The fact that cued recall is generally better than free recall indicates that the cues people use spontaneously are not as effective as those provided in most cued-recall situations.

There are rare cases in which free recall is superior to cued recall, and these cases are diagnostic of the encoding and retrieval processes involved in recall. For example, Reffel (1998) found that college students in the USA were able to freely recall about 41 of the 50 states (82%). However, when recall of the states was cued with a blank map of the United States, recall dropped to approximately 32 states (64%). In contrast to the professor in the example above, clearly those who were engaging in free recall of American states were not cuing themselves by spatially "moving around" a mentally-created blank map, otherwise they should have done at least as well as those actually provided with such a map. Instead, Reffel suggested that the memorial representations formed when students learned the 50 states were verbal rather than visual and so the visual cues provided by the map were not as effective as other verbal cues that people may have spontaneously used in free recall.

Modern research has been focused on the *metacognitive* processes involved in recall. In this context, *metacognition* refers to people's assessment of their own memory system and how well it works. For example, people may be asked to make a *judgment of learning* (JOL) about how well they will remember a target from a cue-target pair (e.g., *ocean–TREE*) when presented with the cue later on (e.g., *ocean–?*). Nelson and Dunlosky (1991) showed that if this judgment is delayed for a short period, JOLs are more accurate than if they are made immediately after studying the pair. One way of explaining this effect is in terms of the types of information that people rely on when making JOLs. Immediately after studying the cue-target pair, both items are in short-term memory making it difficult to use a covert retrieval attempt of the target using the cue as a basis for the judgment. However, if some time passes, and the items are no longer in short-term memory, JOLs may indeed be based more on the success of a covert retrieval attempt, which is a reasonably good predictor of later success.

Other research on metacognitive processes in recall involves trying to separate the front-end components of the retrieval process from the post-retrieval editing processes. Higham and Tam (2005) likened these processes to the generation and recognition processes incorporated in the original generate–recognize models, discussed above. They argued that there are influences on both these early and late selection components of recall and that sometimes the same variable could have opposite effects on each. For example, the higher the strength of the associative relationship between cue-target pairs, the more likely the target will be generated by the cue. However, strong associative relationships make recognizing the target from amongst candidates more difficult because of high inter-candidate similarity. Thus, despite Tulving and Thomson's (1973) influential attack on early generate–recognize theory, the usefulness of the distinction between the early- and late-selection processes that it incorporates has stood the test of time.

Cross-References

- ► Autobiographical Memory
- ► Cueing
- ► Human Cognitive Architecture
- ► Memory Dynamics
- ► Recall and Effect of Repetition on Recall
- ► Retrieval Cues and Learning

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Cueing

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Synonyms

Priming; Prompting

Definition

Cueing has many different definitions in many different contexts. Here, we limit our definition to the context of memory retrieval. Cueing is achieved via prompts or *cues*, which include anything that is connected in some way to to-be-remembered (target) information in long-term memory and which prompt retrieval of it. Cuing can occur for target information in *episodic* memory (memory for events in the personal past that occurred in a particular time and place) or *semantic* memory (memory for generic conceptual information that is context free). Cues for either type of memory can be quite varied. For example, cues for the target TIGER might be external stimuli, such as semantically or associatively related words (e.g., *lion*), incomplete sentences (e.g., *A ____ has stripes*), incomplete pictures (e.g., a line drawing of the outline of a tiger), or letters within a word (e.g., *TI*___). Cues can also be internal. For example, in an attempt to cue retrieval of target information from episodic memory, people might be asked to contemplate what they were thinking about, their mood, or the spatio-temporal context at the time that they encountered target information.

Theoretical Background

Retrieval does not occur in a vacuum, so cueing is critical if retrieval is to be efficient. The most common way of cueing retrieval is with explicit cues such as those used in cued-recall tasks. For example, people may be given cue-target pairs to study such as *lion–TIGER* and later they attempt to retrieve the targets (*TIGER*) in response to retrieval cues that are the same as the cues presented during study (*lion–?*). Other times, *extralist* cues (cues not presented during study) are used. For example, after studying pairs like *lion–TIGER*, an extralist cue such as *stripes–?* might be provided, to which *TIGER* would be the correct response. According to the *encoding specificity principle* (Tulving and Thomson 1973), the most effective retrieval cues are those that were encoded specifically with the target information. Hence, *lion* would be a better cue for the target *TIGER* than *stripes* in this example because *lion* was studied together with *TIGER*. Nonetheless, even extralist cues can be effective for retrieval at times, particularly if they are strongly associated with the target (Higham and Tam 2005). If people are expected to retrieve target information but given no explicit cues at all, then they are engaged in a *free-recall* task. However, even in these circumstances cues are likely to be used, only they are supplied by the rememberer rather than by an external source. For example, in order to retrieve the names of colleagues, a professor might mentally "walk" around her workplace, using spatial memory for the location of offices as internal retrieval cues for the names. Indeed, cueing oneself using memory for geographic locations is the basis of the *method of loci* for remembering unrelated lists of items, a mnemonic technique used as far back as the ancient Greeks. Alternatively, she may rely on external cues to retrieve the names, such as a group photograph of her colleagues.

Important Scientific Research and Open Questions

An important question in psychology is what method of cueing is most effective for retrieval from long-term memory? When retrieving information from episodic memory, it is commonly believed that the principle of encoding specificity applies. That is, the most effective cues are those that were learned along with target information. However, Nairne (2002) has argued that the encoding specificity principle is only part of the story; what is more critical than encoding-retrieval match per se is whether a retrieval cue discriminates the target memory from other candidate memories. Usually, the greater the match, the more a cue specifies a particular target, but this need not be the case. For example, Nairne discusses the case in which people are asked to memorize a list of *homophones* (words that sound the same but have different meanings; e.g., *write, right, rite, write, rite, right...*) and then asked to retrieve the third item in the list. Suppose further that there was an increase in the match between the encoding and retrieval conditions because information about how the target information sounded was included in the retrieval cue ("*the target you are looking for is pronounced* \'rīt\ or *rΛIt*"). Although compared to free recall the match between the conditions of encoding and retrieval is increased with the provision of veridical sound information, and although the detail added to the cue was encoded specifically with the target information, retrieval would be unlikely to improve. The sound of the target is shared with all other candidate memories and so it is not diagnostic of which particular item is being sought. Thus, although it is generally true that the greater the match between the encoding and retrieval conditions, the better is memory performance, the match per se is not sufficient for good retrieval. It is discriminability of the cues – how well they specify a particular candidate memory – that is really the important factor that determines the efficacy of cues.

In many cases, there may be a combination of internal and external cues that uniquely identify specific memories, allowing retrieval to occur without a problem. Other times, however, several of the cues in the cue set may point to more than one memory, causing errors in retrieval. For example, if two different targets are encountered in two different sources where there is a lot of cue redundancy (e.g., the targets *TIGER* and *TABLE* are studied in the same general experimental context but in different lists) then *source-monitoring errors* (e.g., Higham et al. 2011) may occur despite a close match between the encoding-retrieval contexts. That is, the targets may be falsely remembered as having come from the wrong list because very few cues are available to correctly attribute the source of the targets as one list versus the other.

Cues can also be used to prompt semantic memories, that is, generic memories for definitions of words or concepts. A common way to do this is *priming*, whereby the activation of target information in semantic memory is facilitated by simultaneous or prior processing of another item (prime). For example, in *semantic priming*, the presentation of the prime *nurse* shortly before (or along with) presentation of the target *doctor* is likely to shorten the pronunciation latency (the time to pronounce) of the target (e.g., Meyer and Schvaneveldt 1971). In this case, retrieval is not characterized by accessing an event in a person's personal past, as with retrieval from episodic memory, but rather by temporary activation of a particular concept or entry in a lexicon. Unlike cueing of episodic memories, cueing (or activating) semantic memories is not associated with the experience of "reliving" a past event. However, partial cueing of both semantic and episodic memories can give rise to the tip-of-the-tongue state (Brown and McNeill 1966), in which people report the frustrating experience of feeling that the sought-for information is near consciousness, but just out of reach. Sometimes, people can accurately report characteristics of the target information, such as the first letters of the word, or what it rhymes with, without being able to actually name the item. In this case, the subjective experience of cueing is similar despite the difference in the types of memories being cued.

Cross-References

► Autobiographical Memory
► Cued Recall
► Human Cognitive Architecture
► Memory Dynamics
► Recall and Effect of Repetition on Recall

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Cue-to-Consequence Learning

► Selective Associations

Cultural Activities

The process(es) by which people go about collectively making meaning of their lives (through activity) in sociocultural contexts.

Cultural Anticipatory Behavior

► Anthropology of Learning and Cognition

Cultural Aspects of Learning

► Bateson, Gregory (1904–1980): Anthropology of Learning

Cultural Development

► Learning: A Process of Enculturation

Cultural Diversity in Music Education

► Multicultural Issues in Music Instruction and Learning

Cultural Factors in Learning and Motivation

► Cross-Cultural Factors in Learning and Motivation

Cultural Historical Activity Theory

► Cultural-Historical Theory of Development

Cultural Historical Activity Theory (CHAT) Research

► Sociocultural Research on Learning

Cultural Historical Research

► Sociocultural Research on Learning

Cultural Influences on Human Learning

► Cultural Influences on Personalized e-learning Systems

Cultural Influences on Personalized e-learning Systems

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Synonyms

Cultural influences on human learning; Personal learning environment; Personalization in e-learning

Definition

Cultural influences on personalized e-learning occur when online learning system development takes into consideration aspects of cultural influences on human learning when designing the system. Student learning processes are very complicated and are influenced by various factors. There are different characteristics among students who come from different cultures and countries. In the learning environment, students who come from different ethnic groups and cultures require different support. It is essential to obtain personalization in e-learning, to provide suitable support to students' learning activities based on different cultural backgrounds.

Theoretical Background

Research into cultural influences on learning has been recognized in developing a good model for e-learning. Liu (2007, p. 36) captures the essence of culture on learning when he remarks: "*It is not possible, in the view of some scholars, to create a model of the good teacher without taking issues of culture and context into account.*" In the globalized e-learning environment, students coming from different cultures and countries have different characteristics and require different support designed for their approaches to study and learning styles. The study of Boondao et al. (2009, pp. 68–69) has shown that Eastern and Western learners have different study approaches and characteristics which require different support in learning. There are principles that need to be considered when designing a personalized e-learning system for students who have different cultural backgrounds.

- *Educational value differences.* Eastern students and their families place high value on their educational results. Therefore, Eastern students are more serious with their educational results than Western students. In order to answer correctly in an examination, Eastern students expect a very precise answer from their instructors. Instructors and course designers should be sensitive to this issue in providing online course materials for international students.
- *Educational cultural background differences.* A common feature of Eastern tradition educational backgrounds is rote learning. Therefore, Eastern students are less likely to criticize or discuss their opinions in class. When designing a system, instructors and course designers need to provide activities for interaction in the early stages of the online course to encourage participation from the Eastern students.
- *Cultural communication differences.* Eastern cultures tend to be high-context (Kim and Bonk 2002). This means that people from Eastern cultures are indirect, implicit, and reserved in communication. When Eastern students have a difference of opinion with somebody in their class, most prefer to talk to the person privately or they may simply remain silent, as confrontation is seen negatively in their culture, while Western cultures tend to be low-context, which means that they are direct, explicit, and unambiguous in communication. Western students prefer to openly discuss disagreements in class. In addition, Eastern students are more respectful to their teachers. They prefer to listen and get feedback from their instructors rather than peers (Levine et al. 2002). Instructors and course designers should understand this difference as it might cause potential problems with discussion forms in the online learning environment.
- *Different language usages.* Language is closely related to culture. In a globalized e-learning system, students come from a variety of cultural backgrounds; therefore, instructors and course designers should be aware of this issue. Using slang or local idioms may cause confusion to the students who do not have the same culture backgrounds. It is

recommended to use relatively simple sentences for nonnative-speaking students.

- *Learning style preferences.* The learning style preferences among Eastern students and Western students were not statistically significantly different. However, students have different learning style preferences in each culture group. Instructors and course designers need to provide course material that takes into consideration students' individual learning style preferences.

Important Scientific Research and Open Questions

In the context of cultural influences on learning, one active line of research is the cultural awareness in e-learning. The research on cultural awareness in e-learning is made to ensure that culture is taken into account when developing online courses. Cultural awareness is important in communication with people from other cultures. In the internationalized learning environment, students and lecturers come from multicultural education backgrounds. This can influence their ways of understanding education, curriculum, learning methods, expectations, duties, and other activities in the educational process. To avoid lack of understanding, culture has to become a built-in knowledge of each curriculum (Welzer et al. 2010).

Another lively area of research concerns the personalization systems development. Research into personalization in e-learning can be divided into two main directions: adaptive educational systems and intelligent tutors. In an adaptive educational system the presentation of content and the order in which the content is presented to the student is adapted to a student's model. Adaption is achieved by methods such as adaptive ordering, hiding or removing links, and adaptive link annotation. An intelligent tutor is like a computer program that learns what interests a student, his or her preferences and study habits, and provides proactive, personalized tutoring (Schiaffino et al. 2008).

Acknowledgments

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Cross-References

► Cross-cultural Factors in Learning and Motivation
► Cross-cultural Learning Styles
► Cross-cultural Studies on Learning and Motivation
► e-Learning and Personalization
► Personalized Learning
► Personalized Learning Systems

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Cultural Issues in Music Education

► Multicultural Issues in Music Instruction and Learning

Cultural Learning

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Synonyms

Cultural transmission

Definition

Culture can be succinctly described as a process of information transfer within a population that occurs without the use of genetic material. Culture can take many forms such as language, signals, or artifactual materials. Such information exchange occurs during the lifetime of individuals in a population and can greatly enhance the behavior of such species. Because these exchanges occur during an individual's lifetime, cultural learning can be considered a subset of lifetime learning.

Theoretical Background

Cultural learning describes the process of information transfer between individuals in a population through nongenetic means. Typically this is achieved through communication or the creation of artifacts available to all members of a population for the purposes of cultural transmission.

Cultural learning is a model which combines population learning with a modified version of lifetime learning that allows populations to pass on knowledge to the next generation through nongenetic means through a process of communication or artifact creation, often achieved through imitation. Much research has been conducted in the field of imitation, particularly with respect to robotics and symbol grounding in animals and artifacts, and a number of models have been developed to examine the interaction of culture and evolution. In addition, the simulation of culture in populations of artificial organisms has been the focus of much research (Yanco and Stein 1993; Denaro and Parisi 1996; Hutchins and Hazlehurst 1991; Borenstein and Ruppin 2003).

Cultural transmission is the transmission of information resulting from social interactions across and within generations. As such, it is distinct from genetic evolution although, as described further, it can interact with the evolutionary process. Transmission can occur in a number of ways, according to the social interactions in question. Vertical transmission describes the transfer of information from a parent generation to the next, such as occurs between parents and offspring. Horizontal transmission is the transfer of information within a single generation, as occurs when peers acquire behavior through imitation or learning. Finally, oblique or diagonal cultural transmission describes the process where a parent generation transmits information to both its peers and the next generation.

Important Scientific Research and Open Questions

A large body of research exists which examines the evolution and sustainability of language as a means of cultural transmission in populations of artificial organisms. The following subsections highlight some of the leading research in the field.

Belew Experiments

The experiments undertaken by Belew (1990) were among the first to examine the effects of cultural transmission on a population of agents employing a similar model to that employed by Hinton and Nowlan (1987). A mechanism dubbed cultural advantage allowed fit agents to vertically transmit information to their offspring.

The transmission comes in the form of a learning bias, where agents are given a higher chance of selecting the same locus (a "1" or a "0") as their parents to replace their "?" locus. Belew found that the inclusion of this cultural advantage mechanism caused the population to converge more quickly to the problem solution. Furthermore, he noted that genomes began to contain a much higher proportion of "?" loci than the Hinton and Nowlan experiment indicating that the addition of culture reduces selective pressure to find the optimal genome. Finally, oblique cultural transmission was also examined, where fit agents were allowed to share information with both their offspring and a number of peers from the same generation.

Results obtained from the experiment showed that oblique transmission was effectively equivalent to vertical transmission given a population of sufficient size.

Best Experiments

Another variation on the Hinton and Nowlan model is described in the experiments undertaken by Best (1999). The work extended the Hinton and Nowlan model by allowing agents to acquire information socially, not through individual learning. In other words, the stated aim of the work was to observe whether the evolutionary process could be influenced by cultural learning alone, without the presence of any individual learning mechanism.

The cultural learning mechanism is different from Belew's cultural advantage in that it is based on imitation rather than learning bias. Agents communicate through a horizontal cultural transmission mechanism where agents imitate their peers.

Agents are evaluated using an external cultural fitness function and social models are chosen accordingly from the population. A learner is selected randomly from the population and for each "?" locus in its genome, the agent imitates the model agent's value. The process of learning is non-Lamarckian – imitated values are not passed on to the next generation. The experiments demonstrated that horizontal cultural transmission can guide the evolutionary process and that social learning may be superior to conventional lifetime learning, leading to faster convergence.

Indexed Memory and Cultural Artifacts

It has been proposed that instead of agents communicating directly with one another, sometimes in a seemingly random fashion, it may be useful to have them share information through a specified medium (Spector 1994). This medium is more easily observed by the experimenter and direct effects can be produced by modifying its properties.

A population may share its information through a centralized memory repository where individuals can write and read information about their perceived environment. One disadvantage of the approach is that since any agent may write to the shared memory, there is a risk that agents not well suited to their environment could disrupt others by sharing erroneous information.

Lexicon Evolution

The study of communication in artificial populations has led some researchers to include fixed lexicons as a part of their experiment (Cangelosi and Parisi 1998). While this has provided a useful starting point, others argue that the use of a fixed lexicon is not representative of real world language development. Much research has been done focusing on a dynamic lexicon in a population of communicating organisms. Hutchins and Hazlehurst developed an experiment that examined the evolution of a shared lexicon through repeated cultural interactions (Hutchins and Hazlehurst 1991). Each agent in the experiment is represented by a neural network with a fixed structure. The neural network possesses the standard input and output layers as well as two hidden layers. However, the second hidden layer (closest to the output layer) is dubbed the "verbal input/output" layer and is used for agent communication.

Agents are randomly assigned as speakers or listeners, where speakers emit signals from their verbal input/output layer and listeners perceive and attempt to replicate the signals using back-propagation. By iteratively performing these interactions, the researchers were able to show the emergence of a shared lexicon of symbols representing the agent's environment.

Borenstein and Ruppin Experiments

Borenstein and Ruppin suggest that imitative learning can be harnessed in a similar manner to more explicitly cultural means of information transfer (Borenstein and Ruppin 2003). Like cultural learning, learning by imitation is an alternative to supervised learning and dispenses with the requirement for explicit sources of training data such as external oracles. Much research has been conducted in the field of imitation, particularly with respect to robotics and symbol grounding in animals and artifacts.

The model employed by Borenstein and Ruppin consists of a population of evolving agents possessing a genetic encoding of a neural network and assigned a number of benchmark tasks. A number of teachers are selected from the population according to their fitness and agents imitate their behavior using back-propagation. In this sense, the work is similar to research on teacher/pupil interactions as undertaken by Billard (Billard and Dautenhahn 1999). However, in this set of experiments, the researchers limit the behaviors that can be learned by imitation to those acquired innately by the teachers. In other words, pupils may not imitate behavior that the teachers have themselves acquired through learning.

Noise as a Source of Diversity

The success of genetic algorithm approaches to function optimization problems is due in part to the algorithm's capability for novelty arising from mutations.

To investigate whether a similar scheme could be provided for cultural transmission an experiment was conducted (Denaro and Parisi 1996) where a population of agents underwent a process of cultural imitation using the teacher/pupil scenario. The teacher's output to a given situation became the pupil's input to allow the pupil to associate a situation in its environment with a given signal. The experiment used a purely cultural evolution scheme, so no genetic information was passed on to further generations.

It was found that if a population taught the successor generation in the fashion described above, the cultural information passed on would dissipate over generations. This could be reduced by applying a selective process to the choice of teacher, but this only seemed to delay dissipation which was in the end inevitable.

It was suggested that this may have been because of the lack of novelty in the cultural transmission and that an equivalent to the genetic algorithm's mutation operator could be the addition of noise in the signal from teacher to pupil. The results showed that the populations were able to sustain communication systems over successive generations with the inclusion of random noise.

Cross-References

▶ Enculturation and Acculturation
▶ Imitative Learning in Humans and Animals
▶ Learning: A Process of Enculturation
▶ Lifelong Learning
▶ Population Learning
▶ Repeated Learning and Cultural Evolution

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Cultural Mentoring

▶ Developing Cross-cultural Competence

Cultural Models

▶ Anthropology of Learning and Cognition

Cultural Schema–Based Expectations

▶ Anthropology of Learning and Cognition

Cultural Transmission

▶ Cultural Learning

Cultural-Historical Activity Theory

▶ Activity Theories of Learning

Cultural-Historical Theory of Development

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Synonyms

Activity theory; Cultural historical activity theory; Lev Vygotsky's theory of development; Sociocultural psychology; Sociohistorical psychology

Definition

The cultural-historical theory of development is a general metatheory (theoretical framework) of human development introduced by Russian/Soviet psychologist Lev Vygotsky that strongly affected the further progress of developmental and educational psychology.

Theoretical Background

The cultural-historical theory of development sees child development mostly as a social process. Conscience is not given to human beings at birth; it has its genesis and history of development. Vygotsky introduced and argued for a principle of social-historical determination of human mental life and the specificity of its development in the process of ontogenesis. He considered the regularities of human child mental development to be radically different from the regularities of mental development in all other species. This general viewpoint was concretized by Vygotsky in a number of theoretical statements which created a powerful impetus for the further research.

The notion of psychological age. Psychological age is considered to be the unit of analysis for human development. It represents the entire dynamic structure determining the role and specific "weight" of any partial line of development – intellectual, emotional, etc. Psychological age is characterized by its structure and dynamics. The age structure includes two constituents: ► social situation of development and age-related psychological new formations (neoformations in several translations from Russian into English). The notion of the *social situation of development* is opposed to the understanding of social environment as a factor of development in traditional psychology. As Vygotsky explains, "at the beginning of each age period, there develops a completely original, exclusive, single, and unique relation, specific to the given age, between the child and reality, mainly the social reality, that surrounds him. We call this relation the *social situation of development* at the given age" (Vygotsky 1998, p. 198). The new formations "characterize the reconstruction of the conscious personality of the child in the first place" and "are not a prerequisite but a result or product of development of the age level. The change in the child's consciousness arises on a certain base specific to the given age, the forms of his social existence. This is why maturation of neoformations never pertains to the beginning, but always to the end of the given age level" (Vygotsky 1998).

Vygotsky distinguishes the "near" and "distant" relations of a child to society. The first category describes the relation "child–close adult and peer," which realizes individual–personal relations. The second category characterizes the relation "child–social adult," in which the adult plays the role of a representative of social requirements, norms, and societal meanings of activity. Vygotsky defines the age-related new formations as both the brand new type of composition of a child's personality at a particular stage of development and the activity which appears for the first time during that stage and defines the child's conscience, its attitude toward the social environment, its external and internal life, and the whole course of its current development.

With regard to the dynamics of transition from one age period to another, Vygotsky distinguishes two types of age-related changes: (1) gradual, slow, mostly quantitative change, i.e., evolutionary type of changes, and (2) fast and deep fundamental transformations, affecting all sides of the child's personality, i.e., revolutionary changes. The evolutionary type of development is typical for stable or lytic ages, the revolutionary type of development for critical ages, for age-related crises. The main function of the age-related crises is to resolve contradictions which emerged in the course of the child's mental development. The essence of the contradictions is a discrepancy between the previous stage of social situation of development and the current level of the child's achievements in the new formation.

In the process of the child's development in the current stage, the social situation of development breaks down, reflecting in its transformation new achievements and preparing the child for the new social situation of development.

Doctrine of Higher Mental Functions

Vygotsky introduced the notion of *higher mental functions* as opposed to the elementary (natural) mental functions. Unlike the elementary (natural) mental functions, the higher mental functions are not inborn but rather are the product of social and historical development; their occurrence is determined by the features of human life. Signs and meanings mediating the higher mental functions are psychological tools for human mental activity which are functionally similar to common household tools. Logical thinking, voluntary memory, and voluntary attention may be considered as examples of the higher mental functions, while verbal meanings, math signs, mnemonic techniques, etc. serve as psychological tools. The higher mental functions are characterized by their "double sociality" – by structure (mediated by social signs and meaning) and by origin (occurring only in the process of communication) (Vygotsky 1978). On the basis of this statement, Vygotsky formulated his famous "general genetic law of cultural development," which declares that any function in the child's cultural development appears twice: first between people as an inter-psychological category, and then within the child as an intra-psychological category (Vygotsky 1978).

On the role of social environment in child mental development. According to Vygotsky social environment is a source of child development as it contains a system of cultural tools, signs, samples, the appropriation of which initiates the development of higher forms of human mental activity (higher mental functions). Vygotsky does not juxtapose environment and child as two different essences because the child is a part of its environment. To clarify the role of social environment, one has to explore the significance of the environment for the child, its attitudes to the various aspects of environment. The social situation of development as a system of interrelations between the child and its social surroundings presupposes the child's own activity constructing such interrelations.

On Interconnection Between Instruction (Education) and Development

Starting from his doctrine of nature and the genesis of higher mental functions, Vygotsky considered instruction as a driving force of development in accordance with the following logic: Instruction provides a child with examples of the higher mental functions, and since a transition from the natural (elementary) mental functions to the higher ones is an indicator of mental development, instruction is good only when it precedes development (Vygotsky 1978). However, by no means can all kinds of instruction "precede development." Such instruction has to be organized inside the zone of the child's proximal development, and its situation should be dictated by the system of scientific concepts (Vygotsky 1978). Vygotsky claims that "instruction cannot be identified as development, but properly organized instruction will result in the child's intellectual development, will bring into being an entire series of such developmental processes, which were not at all possible without instruction" (Vygotsky 1962, p. 108). Moreover, an instructional strategy designed in accordance with the zone of proximal development "integrates several approaches to form a comprehensive agenda for research of the genesis, development, function, and structure of the human psyche" (Vygotsky 1962, p. 121).

Important Scientific Research and Open Questions

The key constituents of the Vygotsky's cultural-historical theory of development are the following: the doctrine of the structure and dynamics of psychological age as the unit of analysis of human mental development; the principle of the cultural-historical determination of human mental development and the specificity of human mental development as the formation of the higher mental functions; criteria of human mental development: occurrence of higher mental functions, age-related psychological new formations, changes in systemic and sense structure of human conscience; introduction to the law of development of the higher mental functions as the process of internalization; the leading role of instruction for child mental development; criteria for developing instruction (instruction aimed at the appropriation of the system of scientific concepts inside the zone of the proximal development); new psychological investigation strategy: the experimental-genetic method.

In their preface to the first posthumous Russian edition of the selected works of Vygotsky, published in 1956, his closest pupils and followers A. Leontiev and A. Luria listed the following shortcomings of the theory: (1) The opposition of natural and higher mental functions is problematic. (2) It concentrates excessively on sign structure and as a consequence intellectualizes child development. (3) It takes insufficient account of the role of real child activity. One may easily add one shortcoming more: Vygotsky fails to operationalize key concepts (such as the social situation of development, the zone of proximal development, et al.).

From the 1950s to the1970s, Russian scholars further developed the cultural-historical approach to human development established by Lev Vygotsky (A. Leontiev, A. Luria, A. Zaporozhets, L. Bozhovitch, P. Galperin, V. Zinchenko, V. Davydow, M. Lisina, and many others). These developments were concerned with the role of child activity, especially of the so-called leading activity, the role of communication in development, the functions, structure, and regularities of child communication development, the problem of the periodization of mental development, and the process of internalization of initially external forms of child activity. This constellation of psychologists also pointed out similarities and differences between Vygotsky's and Piaget's theories of child development and explored them experimentally.

Broad and active discussions on the pros and cons of Vygotsky's legacy did not start in the West until the late 1970s (M. Cole, J. Wertsch, A. Brown, B. Rogoff, S. Scribner, et al.) but have intensified substantially during the last two decades (R. Van der Veer, J. Valsiner, I. Arievitch, A. Stetsenko, Y. Engeström, H. Daniels, J. Hautamäki, M. Hedegaard, et al.) and continue today.

When assessing Vygotsky's contribution to the construction of an innovative theory of child (human) development, one should not forget that most of his revolutionary ideas were introduced more than 80 years ago and were marked by the natural limitations of his time and the stage of development of world psychology.

Cross-References

► Activity Theories of Learning
► Development and Learning
► Internalization
► Learning Activity
► Social Construction of Learning
► Vygotsky's Philosophy of Learning
► Zone of the Proximal Development

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Culturally Responsive Teaching

Using the cultural knowledge, prior experiences, frames of reference, and performance styles of ethnically diverse students to make learning encounters more relevant to and effective for them (Gay 2000).

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Culture

The system of social mores, behavioral standards, symbols, worldviews, and beliefs that provide meaning and structure in a person's life. According to Valerie Pang's 2005 book, *Multicultural Education: A Caring-centered, Reflective Approach*, culture is comprised of three layers of acquired knowledge: (a) language, symbols, and artifacts (means of communication), (b) customs, practices, and interactional patterns (means of interaction), and (c) shared values, beliefs, norms and expectations (values driving people and/or groups).

Cross-References

► Openness to Experience

Culture and Learning

► Identity and Learning

Culture and Learning and Motivation

► Cross-Cultural Factors in Learning and Motivation

Culture in Second Language Learning

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Synonyms

Beliefs and values; Civilization (archaic); Social norms; Way of life; Worldviews

Definition

The term "culture" is famously difficult to define. Within the research on language teaching and learning, the term "culture" has diverse and disparate definitions that deal with forms of speech acts, sociocultural behaviors, social organizations, knowledge constructs, and ways in which knowledge is transmitted and obtained. Culture is sometimes identified with and may find its manifestations in notions of personal space, body language, eye contact, concepts of time, and various customs and traditions.

Theoretical Background

In the early 1900s, linguists and anthropologists who researched the structure of American Indian languages, e.g., Franz Boas (1858–1942), found that relationships among thought, abstract notions, and language as a means of expressing ideas and concepts was complex. In the 1920s, following Boas, Edward Sapir (1884–1939) and his students concluded that a language and the culture of its speakers cannot be analyzed in isolation. According to Sapir, language can be seen as a way to describe and represent human experience and understanding of the world, and typically, members of a language community share common systems of beliefs and assumptions in regard to how the world is constructed. Their views of objective phenomena and shared beliefs and histories are communicated through language, and communication establishes a connection between language and the culture of a community.

In a number of important studies published between the 1920s and the 1950s, Sapir and Benjamin Whorf (1897–1941) further determined that, in different languages, linguistic systems, discourse (units of connected speech and writing), and word meanings demonstrate different ways of looking at the world and constructing its realities. To Whorf, for example, differences in word meanings reflected the thought processes that set American Indian ► worldviews and beliefs apart from those of Europeans in their definitions of time, space, and a broad range of natural phenomena. Although various languages often have distinct grammar attributes and lexicon (vocabulary), it may be misleading to define the differences among languages exclusively in terms of word meanings and grammar rules. The Sapir–Whorf hypothesis of linguistic relativity also applies to a great many abstract features of lexical, grammatical, referential, and communicative systems.

In the 1960s and 1970s, investigations of the connections between language and culture produced such impressive and seminal works as those by Dell Hymes and John Gumperz on interactional sociolinguistics and Edward Hall on behavior and cognition. In their publications in the early 1970s, Hymes and Gumperz and Hymes (1972) advocated the view that the uses of language and its analyses are inextricable from the society and its cultural norms. Language users' social backgrounds and identities, as well as social meanings, are conveyed by means of language. Hymes (1972) noted that in linguistics, a descriptive theory of speech and interaction has to take into consideration how language is used in a particular community both in speech and writing. According to Hymes, language in interaction is defined by social and language ► norms for the use of speech, as well as their communicative content, linguistic form, interactional setting, and social goals. Speech events and speech acts are not universal and are fundamentally defined by the social structure, ► values, and beliefs, and the sociocultural order of the community. Hymes (1972) was also the first to introduce the notion of "communicative competence" that in the last half a century has had an indelible effect on second language research and pedagogy.

In the 1980s and 1990s, educational and linguistic studies investigated manifestations of culture in language teaching and learning and concerned primarily the effects of body language, eye contact, and other overt communicative behaviors. Comparisons of culturally defined behaviors focused on such common anthropological constructs as hand and head movement, eye contact, lexical references to broad-range tangible and abstract entities (e.g., measures of distance, shapes, colors, and time), forms of address, or terms of kinship and personal relationships that do not exist outside the specific societies in which they are used. In the 1980s and 1990s, language teaching methodologies began to include various techniques for analyzing and teaching cultural behaviors together with instruction on second language skills. Many such teaching techniques associated with culture learning, however, encompassed primarily the anthropological views of culture and only briefly touched on underlying cultural assumptions, beliefs, and values (e.g., metaphors or conversational norms) that are invariably reflected in language uses and interaction.

At present, two parallel strands of research have evolved to identify the role of culture in society and its influence on human behavior and language use. The first strand includes studies of culture as it applies to ► social norms, ► beliefs, assumptions, and ► value systems that affect practically all human activities and is prevalent in the domains of anthropology, sociology, ethnography, and intercultural communication. Research in these disciplines examines culture as it applies to the structure of human societies and organizations, as well as the differences and similarities that exist in ► social worldviews. Applied linguistics, and sociolinguistics in particular, undertakes the study of the interconnections between language and ► sociocultural norms and societal frameworks. Specifically, the subdisciplines of sociolinguistics and pragmatics have the goal of analyzing how members of particular cultures use language to refer to, describe, or function within social organizations. For example, politeness is considered to be a universal feature of language use in social organizations, but its pragmatic, linguistic, social, intentional, and conceptual realizations vary substantially among different languages and cultures. Even speakers of the same language, such as Chinese or Spanish, or different dialects, e.g., American, British, or Indian English, may belong to different cultures or subcultures and thus have different notions on what it means to be polite and how politeness should be realized in speech and behavior.

The second strand of research in anthropology, ethnography, and applied linguistics also includes studies of specific cultures, such as Brazilian, Chinese, Japanese, or Korean. Such studies examine and describe ways of doing, speaking, and behaving in specific cultural and language communities, without necessarily undertaking to identify commonalities and differences among various cultures. Both research into culture in general and specific cultures can be useful to language teachers and learners who seek to raise their awareness of the inextricable relationships between the culture of the community and the language usage of its speakers.

Important Scientific Research and Open Questions

In second language pedagogy, a dominant perspective has emerged that language usage and the culture of its speakers are closely bound up, and, together, they constitute a unified domain of sociolinguistic experience. Many researchers in language learning and methodologists in language teaching currently hold the view that it is simplistic to imply that culture can be examined, taught, and learned through exercises on reading news media reports and advertisements. Few believe that folklore, festivals, facts, and foods (the 4-F approach to teaching culture) are directly relevant to the impact of culture on learners' linguistic production and interactive behaviors.

A substantial body of research has demonstrated convincingly that various aspects of second language learning are affected by the interpretive principles and paradigms in learners' natal cultures. Specifically, language learners' understanding of conceptualizations and constructs in second culture is crucially affected by their culturally defined assumptions, presuppositions, beliefs, and worldviews. For example, for learners socialized in the cultures with a strong tradition of deference to elders, more egalitarian terms of address, such as the use of a first name, may seem somewhat inappropriate at best.

The teaching and learning of sociocultural and linguistic norms implicitly or explicitly pervades the teaching of conversational discourse, social interaction, and the spoken and written language typically employed in a language community. Second language learners inescapably become learners of the second culture because a language cannot be learned without considering the cultural context in which it is used (Hinkel 1999).

In the current understanding of the place of culture in second language pedagogy and learning, the work of Michael Byram has played a prominent role. Byram (1989, p. 1) noted that culture represents a "hidden" curriculum in second language teaching. That is, language teaching can rarely take place without implicitly teaching the culture of its speakers because language invariably refers to their common and shared knowledge and perceptions of the world, as well as the concepts of culture, and cultural learning. Currently, many researchers and language teaching methodologists largely assume that, in real terms, communicative competence involves socially and culturally appropriate language use, which is almost invariably culture specific.

Unlike the foundational language skills, such as speaking, reading, or writing, second culture does not represent a separate domain of language instruction. Rather, the learning of the second culture makes learners better – and more competent – communicators. In language learning, the foundational sociocultural principles that determine the norms of appropriate language use and behavior within the social networks and paradigms represent the invisible culture (Hinkel 2001). As Stewart (1972, p. 16) comments, "[t]he typical person has a strong sense of what the world is really like, so that it is with surprise that he discovers that 'reality' is built up out of certain assumptions commonly shared among members of the same culture. Cultural assumptions may be defined as abstract, organized, and general concepts which pervade a person's outlook and behavior." To members of a particular community and culture, these fundamental assumptions usually appear to be self-evident and axiomatic. On the other hand, they are not always shared by members of other language communities and cultures whose values are similarly based on unquestioned fundamental assumptions and concepts. It is also important to acknowledge that ways of using language (e.g., speaking, listening, reading, and writing) and sociocultural frameworks in different communities may conflict to varying extents (Hinkel 1999).

The conceptualization of culture as inextricable from ethnolinguistic and personal identity, however, leaves open the question of whether adult learners can be fully socialized in a second culture. Learners' awareness of sociocultural norms and frameworks and the concepts they acquire as a part of their socialization into assumptions, beliefs, and behaviors remain predominantly first culture-bound even in the case of advanced and proficient second language users. As many researchers have noted, language learners cannot simply shed their own cultural identity and fully adopt another because their natal culture is a part of themselves, and their socialization processes have formed and created them as social individuals (Byram and Morgan 1994).

Without an understanding of the manifestations and outcomes of sociocultural values, norms, and concepts on speech and behavior in language use, it may not be possible to become fully linguistically competent in another language. Being aware of the sociocultural frameworks does not mean, however, that learners have to become "native-like," but an awareness of the second cultural norms can allow learners to make their own informed choices of what to say and how to say it. Because language use reflects the culture of its speakers in a myriad of ways, teaching the second culture together with the essential linguistic skills more adequately represents the connections between language and culture than teaching second language linguistic skills – or culture – in isolation.

Cross-References

► Cultural Learning
► Language Acquisition and Development
► Second Language Learning
► Social Influence and the Emergence of Cultural Norms
► Value Learning

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Culture of Learning

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Synonyms

Attitudes toward learning; Reinforcing the value of learning

Definition

It is by no means an exaggeration to state that there is no other word whose definition proves to be that problematic and incomplete as the definition of the word *culture* for both scholars and the laymen. According to *The Oxford Companion to English Language* the first meaning of the term, tillage of the soil, still is in usage in the sense of raising plants and animals and in the scientific "culturing" of microorganisms and tissues. The second meaning which denotes a sense of training (body, mind, ideas, tastes, or manners) underlies such phrases as *physical culture* and a *cultured manner.* A third sense, as in the twentieth-century Western culture, refers to a social condition, level of civilization, or way of life (McArthur 1992). Culture of learning then refers to the social conditions under which learning takes place. While in broader terms culture of learning denotes the attitudes of people from different culture toward learning, in a narrower sense it denotes the physical and psychological conditions in a school environment efficient in leveraging learning through reinforcing the value of learning. Likewise, in broader terms *culture* is not considered as an entity apart from learning, but as a closely related factor with learning and in narrower terms students' achievement is expected due to not only concrete factors such the time and energy students assign to their studies, the facilities they have both at home and at school but also some abstract factors such as the attitudes of teachers, parents, and students toward learning (Kumpulainen and Renshaw 2007).

Theoretical Background

Embedded in the definition of culture is that culture has its start with mankind and end with mankind. Likewise we should acknowledge the fact that learning is not limited with time and space. Culture of learning thus involves enabling students to grasp this fact by heart and it implies a substantial change in the attitudes of students toward learning. Given the fact that in the history of teaching much importance has been put on the role of parents and teachers, we believe, "culture of learning" will reveal to us the extent to which working with peers in team environments and students' motivating each other thus enhancing learning.

Within the concept of culture of learning, learning is considered as a competitive process "through which cultural resources are distributed within specific local groups of learners and more broadly throughout a society" (Kumpulainen and Renshaw 2007, p. 111). Thus learning is not seen simply as a technical matter of effectiveness and efficiency but it is always a normative and ethical endeavor. The individuals of a society are either promoted to or denied from value-laden resources that affect the level and kinds of participation that individuals might achieve in a community (Kumpulainen and Renshaw 2007). Learning extends our lives into new dimensions. It is cumulative. Instead of diminishing in time, like health and strength, its returns go on increasing.

A deep understanding of culture and learning is important for all educators, though the subject must be addressed carefully. The relationship of the values of the culture in which a child is currently living, or from which a child has roots, and the learning expectations and experiences in the classroom are directly related to the child's school academic, social, and emotional success. If a classroom teacher is to facilitate successful learning opportunities for all learners, he or she must "know" the learner. This includes knowing about the individual's personality, learning styles and preferences, as well as the acquired cultural values that affect behavior.

Students whose families value collaboration are known to be independent, and exercise self-control due to the value given to spontaneity. And, students who are rewarded in their families for being social are known to work quietly and alone when needed. Every child of every culture, race, ethnicity, socioeconomic status, gender, age, ability, and talent deserves to have an equal opportunity to be successful in academic and social life (Martin and Nakayama 2008). Teachers who understand learning and cultural differences will strive for intentional variety in instruction, curriculum, classroom management, and assessment, which in turn reflects on the learner's learning behavior. Administrators who believe in learning styles and the variety of cultural characteristics actively value differences in teaching styles. Curriculum designers who practice a learning styles approach encourage diverse programs in classrooms, schools, and the district.

They can increase awareness of individual learning styles and cultural differences through encouraging and supporting appropriate professional development experiences for all levels of school personnel, including their own. For instance, characteristics concerning eastern and western cultures should be taken into account by any curriculum designer, administrator, and teacher while creating a learning environment. Such characteristics may roughly be summarized in the table below:

Dominant themes in an eastern culture	Dominant themes in a western culture
Relaxation; acceptance; contemplativeness; part of nature; silence; meditation; consideration of others' feelings; content with less material assets; love of life; austerity; cherishing wisdom of years; retirement to be with family; teachers and textbooks; coordination of group support; social and moral learning; hierarchical relations	Activity; assertiveness; confrontation; diligence; coexistence with nature; speech; articulation; self-assuredness; attempting to get more of everything; success; achievement; cherishing vitality of youth; retirement to enjoy rewards of work; communicating and learning; teachers as organizers, mentors, guides; horizontal relations

Important Scientific Research and Open Questions

Students' attitudes in a formal learning setting display differences in terms of learning viewed by these two cultures. In western culture, active initiation of discussion and spontaneous and detailed comments are encouraged (Samovar and Porter 2003) while in an eastern culture, attentive listening and brief comments after contemplation are expected. When faced with a problem, westerners value *confrontation* which involves reporting one's feelings honestly and expecting reciprocal honesty (Stewart and Bennett 1991). This contrasts with an eastern culture where harmony is of prime value (Nakayama 1994) and where *confrontation* should be avoided as much as possible.

In eastern cultures – particularly Asian – influenced by Confucianism where students are expected to respect and not challenge their teachers, many students hesitate to voice obvious objections whereas western students are less likely to be so inhibited.

The second important difference between east and west is *competition* that is the primary method among westerners is to motivate members of groups (Stewart and Bennett 1991) while eastern people in general value cooperative attitudes (Nakayama 1994). These characteristics may prove very constructive for both types of learners in a class setting where teachers could on one hand encourage competition leading to excellence, and on the other, promote cooperation among individuals leading to solidarity.

Efficacy differs between two cultures. While western culture values pragmatism where the focus is on getting things done (Stewart and Bennett 1991), eastern culture generally prioritizes other people's feelings. Thus, while a class may evolve more in a process-oriented setting regarding students belonging to an eastern culture, in a western society, the focus may be on product rather than process. Therefore, teachers should be aware of such culture-specific learning values.

Another different aspect is that eastern students have a culture that is geared much more to academic education than those are in a western culture. As a result of such a cultural emphasis on eastern students to excel academically, they inevitably spend more time studying and doing homework than their western counterparts. This may be due to the fact that western teachers themselves do not stress the importance of homework relative to other educational activities. In other words, western students may not regard it as important as eastern students do whether the homework itself is depicted as important or not. This may be a plausible reason as to why some western students choose to fly through their homework without trying to really understand the concepts or why their parents allow them to do homework while watching television. Students' concentration level is inherently abated if they perceive the diminished value of doing homework, not to mention the intrinsic value, to be rather poor at best.

We make meaning based on our experiences and on the information and ideas we encounter. Based on these experiences, we interact with other people. In order to enable our interaction to be effective, we first should recognize other people's differing viewpoints and interpretations. In that sense, teachers or curriculum designers should be aware of the fact that their interpretation may differ depending on students cultural backgrounds. Recognizing each other's viewpoints and interpretations will prevent us from imposing our own views on others and contribute to reforming each other's social identities.

Learning should aim not only at helping students learn the content of the class itself but also understand its cultural background. Therefore, it is important to learn with each other what the expectations in another culture are in particular situations. One culture may give priority to verbalizing what people think spontaneously and clearly while another may prioritize considering others' feelings before expressing whatever occurs in the mind. By understanding each other's different viewpoints, we will gradually be able to acquire shared meanings indispensable for smooth communication. It is up to the teacher to create opportunities so that effective education can be realized by motivating students, most of which depending on our understanding and appreciation of our students' different characteristics, needs, styles, preferences, beliefs, and attitudes. It is only then we can ensure the maintenance of such motivation leading to the emergence of a healthy learning environment.

Cross-References

► Cross-Cultural Factors in Learning and Motivation
► Cross-Cultural Learning Styles
► Learning-Related Motives and the Motivational Quality of the Learning Environment

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Culture-Bearer

A resource person who is a member of the culture being represented or studied.

Culture-Within-a-Culture

► Microculture of Learning Environments

Cumulative Learning

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Synonyms

Incremental learning; Layered learning

Definition

Intelligent systems, human or artificial, accumulate knowledge and abilities that serve as building blocks for subsequent cognitive development. *Cumulative learning* (CL) deals with the gradual development of knowledge and skills that improve over time. In both educational psychology and artificial intelligence, such layered or sequential learning is considered to be an essential cognitive capacity, both in acquiring useful aggregations and abstractions that are conducive to intelligent behavior and in producing new foundations for further cognitive development. The primary benefit of CL is that it consolidates the knowledge one has obtained through the experiences, allowing it to be reproduced and exploited for subsequent learning situations through cumulative interaction between prior knowledge and new information.

Theoretical Background

In cognitive and educational psychology, it has been widely stated and often implicitly accepted that the learning of humans and other animals is *cumulative* by nature. Langley (1995) states that “learning can occur in any domain requiring intelligence” and that it consists of “the improvement of performance in some environment through the acquisition of knowledge resulting from experience in the environment” (p. 1). CL in machine learning presupposes the comparison of information and puts it in a framework for use with future processes or problem-solving tasks.

Among the various aspects of learning, accumulation of knowledge appears to be an essential mechanism, both for acquiring useful abstractions that promote analogical transfer and for producing new foundations (e.g., schema induction) for further development in learning. Everything is learned in connection with other things and the accumulated knowledge serves to form the building blocks of subsequent schematization. This schematized knowledge structure then produces new foundations for further cognitive development over time. Through a schematization, a learner organizes perceived or learned information into many schemas, which consist of groups of generalized concepts at different levels of abstraction.

CL involves using the results of prior learning to facilitate further learning. New information is integrated into previously acquired knowledge through analogical knowledge transfer, thereby improving the learner’s knowledge. This is closely related to the mechanism of *schema-based learning* (SBL, see schema-based learning), which builds on the schema theory. The theoretical assumption of SBL is that newly gained knowledge is assimilated into pre-existing knowledge and organized to form schemas. In SBL, learners extract information from a single example of successful task completion through the processes of generalization/specialization and abstraction/concretion. Learners interpret unfamiliar or new learning situations by activating pre-existing schemas and constructing new schemas. Hence, SBL allows the incremental development of complex cognitive structures through aggregation from stable units of schemas to more complex interactive structures. In the field of artificial intelligence, SBL means a generalized framework for designing integrated adaptive autonomous agents aiming at the incorporation of general principles of adaptive organization and coherence maximization. Furthermore, SBL allows the development of increasingly complex patterns of interaction between the agent and its environment by confining statistical estimation to a narrow criterion. This is consistent with the core mechanism of CL, namely, the gradual development of knowledge and skills that improve over time.

Rumelhart and Norman (1978) distinguish three basic forms of cognitive learning: (1) *accretion*, the encoding of new information within the context of existing instantiations of schemas; (2) *tuning*, the gradual modification and refinement of a schema through experience; and (3) *restructuring*, the process whereby new schemas are created. Accretion and tuning may be seen as corresponding largely to the idea of aggregation as found in the field of AI, whereas analogical knowledge transfer presupposes a restructuring or reorganization of knowledge structures.

Cognitive approaches of learning, such as Ausubel’s assimilation theory or the theory of generative learning (Wittrock 1991), basically assume that a learner consistently reviews information which enhances the learning of new concepts. This in turn strengthens the learner’s long-term memory, thereby allowing him or her to reach a high level of automated knowledge and abilities. Once a learner has acquired knowledge by accumulating information, then he or she integrates and organizes these pieces of knowledge into different levels of cognitive conceptual units (i.e., schemas, scripts, or frames) depending on their various levels of complexity. Throughout this extensive process, these units of knowledge become increasingly routinized and automated. In other words, the learner progressively develops his or her performance from slow, blundering, conscious, and difficult to more rapid, accurate, unconscious, and effortless automation. This automation in performance occurs as the learner consistently links and associates the new information to his or her prior knowledge through extensive practice. Furthermore, these highly automated pieces of knowledge and skills are continuously tuned over time through considerable amounts of "deliberate practice" (Ericsson et al. 1993, p. 363), helping the learner to gain various levels of expertise. Consequently, learning situations should focus on the important synthetic structural links and association to ensure the gradual development of knowledge and skills and hence optimize performance.

Shuell (1986) states that cognitive psychology has influenced learning theory and research in several ways, including (a) the view of learning as an active, constructive process as formulated by Ausubel (1960), who believes a learner's present cognitive structure constitutes the principal factor influencing whether or not he or she will be able to acquire and retain particular information; and (b) the cumulative nature of learning and the corresponding role played by prior knowledge. Shuell, in particular, stated that learning is cumulative in nature and that everything has meaning or is learned in connection. Furthermore, cognitive conceptions of learning have considerable importance through prior knowledge. This argumentation corresponds to a great extent with Gagné's idea of cumulative learning.

Cumulative Learning in Educational Psychology

Gagné (1968) coined the term "cumulative learning theory" on the basis of the assumption that intellectual skills can be broken down into simpler skills. He believed that "learning is cumulative" (Gagné 1965, 1968, 1970) and that human intellectual development consists in building up increasingly complex structures, the learning of higher-level skills such as rules and principles depending primarily upon the prior mastery of subordinate skills or concepts. He also viewed the process of learning as an accumulation of increasingly complex interacting structures of learned capabilities. These structures are capable of interacting with each other in patterns of great complexity, thereby cumulatively generating an ever-increasing competency level. Therefore, any learned capability at any stage of the learning sequence can operate to mediate learning that was not otherwise deliberately taught. Consequentially, generalization or transfer of knowledge to new tasks is an effect of CL. Learning occurs not only in the acquisition of new associations but also because the learner learns the process of classification, differentiation, recall, retention, and transfer of learning due to its continuing cumulative effect. Thus, Gagné assumed a cumulative organization of learning events based on pre-existing relationships among learned behaviors. Hence, he posited that instruction should provide a set of component tasks and a sequence of those tasks to ensure the learners' mastery of each component task and the optimal transfer of the final task. He tried to empirically demonstrate the effect of CL using Piaget's classical conservation task. Though he was criticized for his incorrect analysis of the conservation task example because he used an ambiguous combination of "nonmetric judgment of volume" and "conservation of identity" in his analysis whereas his specific task example presents only the latter, this can hardly degrade the implication of this example in terms of demonstrating cognitive development process (see Furby 1972).

Many authors have emphasized the cumulative nature of learning. Bruner et al. (1956) defined concept learning, also known as category learning and concept attainment, as "the search for and testing of attributes that can be used to distinguish exemplars from non-exemplars of various categories" (in the reprinted version: 1986, p. 233). Consequently, concept learning requires a learner to compare and contrast categories based on the relevance of their features. Bruner (1960) viewed learning as an active process in which learners construct new concepts based upon their present and prior knowledge by means of selecting and transforming information, constructing hypotheses, and making decisions based on a cognitive structure (i.e., schemas and mental models). He hypothesized that "any subject can be taught effectively in some intellectually honest form to any child at any stage of development" (1960, p. 33). Accordingly, he emphasized the importance of learning the underlying principles of different concepts of children's learning in a way that allows the subsequent transfer to be made and consequently expands their knowledge. Bruner also noted that arranging information in a spiral fashion helps children to organize knowledge into a structure that makes it increasingly usable in other areas beyond the current learning situation. Thus, he emphasizes that the learning situation should help learners to actively reorganize the new information, allowing them to build on existing knowledge in a meaningful way and use the newly gained knowledge effectively in future tasks. In other words, in the course of learning situations, repeatedly presented information is organized from the simple to the more complex, from the general to the specific, and is examined in association with other information. Accordingly, Bruner believed that as children grow, the curriculum should repeatedly represent previously learned information and expand on it until the child understands the information and its relations more completely.

Ausubel argued that human cognitive structure is organized hierarchically from greater to lesser inclusiveness (Ausubel and Robinson 1969). New information is subsumed into an existing cognitive structure. In other words, new incoming information can be connected to relevant existing cognitive structure through the process of *subsumption* (Ausubel 1963). Learners activate their pre-existing knowledge so that it can be assimilated, tuned, and restructured into new schemas by meaningful learning (Ausubel 1968). Hence, meaningful learning can help learners to activate pre-existing schemas more effectively and allow them to use their old knowledge in the new learning situation more effectively.

Aebli (1973) defined concepts as the "basic blocks of any discipline," and once these basic concepts are mastered or acquired, the student is ready to take his knowledge to a higher level. These accumulated concepts lead to the higher level of knowledge. According to Aebli, knowledge is acquired as a learner actively constructs and transforms it by integrating newly gained information into an earlier knowledge structure through a process of modification and reinterpretation of existing knowledge in light of the newly gained information. Moreover, such integration promotes the activation of other closely related areas of knowledge in that it cumulatively disposes the learner to learn more.

Cumulative Learning in Artificial Intelligence

In the field of machine learning, information is compared and put into a framework to be used for upcoming processes or problem-solving tasks. Pfeffer (2000) defines a cumulative learning agent as one that learns and reasons as it interacts with the world by using its accumulated knowledge and its observations. Michalski (1994) views learning as "a goal-guided process of modifying the learner's knowledge by exploring the learner's experience" (p. 3) in his *Inferential Theory of Learning* (ITL). In ITL, the learning process consists of the input facts, the background knowledge, and the types of inferences (i.e., induction, deduction, and analogy) a learner makes to generate new knowledge. Thus, the changes in the knowledge content, its organization, and its certainty are all seen as bringing about a total change in the learner's knowledge in the course of learning. Successfully learned knowledge is assimilated into the learner's background knowledge and can be used in subsequent learning processes.

Zhou (1990) introduced the CSM (*classifier system with memory*), an extension of the classifier system model that includes mechanisms for analogical and cumulative learning, and tested it in the domains of robot navigation and letter extrapolation. The CSM was designed in response to the problems of conventional *expert systems*, namely, the fact that they do not acquire automated knowledge, update it to any substantial extent (i.e., adding and removing knowledge), or function intelligently beyond their current knowledge. It can preserve problem-solving expertise, recall similar solutions by searching its long-term memory, construct solutions to similar new situations using analogy (i.e., recognizing the similarities between two problems), and adapt them to fit new situations. Rules created by information exchange are stored in a temporary knowledge base. When a set of detectors relays external information to the system, eligible rules may be triggered, which in turn generate new messages and then perform actions. The system's behavior can be changed through the deletion, modification, and creation of rules (i.e., tuning). While the short-term memory (STM) stores previously accumulated active knowledge, valuable inactive information is also maintained separately in the long-term memory (LTM), thus preventing rapid forgetfulness over time and preserving the information for future use. In other words, when the system has accumulated sufficient knowledge, it *categorizes* and *generalizes* a set of successful task-independent rules by extracting the common features from a set of relevant rules and then *transfers* them from STM to LTM, where it *stores* them as chunked building blocks, organized and indexed hierarchically (from specific to general) for future problem-solving situations. The CSM shows that "with the benefit of the prior experience and accumulation of problem solving expertise, it constructs its knowledge base incrementally through interaction with its environment and improves its problem-solving ability over time" (p. 404). This is consistent with the principle of CL.

Regarding the cognitive processes which are inherent to CL, a distinction can be made between (a) the *aggregation* of knowledge, (b) the *abstraction* of knowledge, and (c) a combination of *aggregation and abstraction* of knowledge. While aggregation of knowledge means that multiple units of packets of knowledge are at the same level of knowledge structure, abstraction of knowledge means that they are at higher level on the hierarchy of knowledge structure.

Aggregation

In the process of aggregation, a learner extracts and identifies information and knowledge and then puts that knowledge into a coherent knowledge structure. Bruner (1960) terms this process *categorization*. A learner categorizes knowledge on the basis of its surface and structural similarities. The process can also be called "structural mapping" (Gentner 1983), which means that a learner maps the knowledge from model A to model B by analogy. Structural mapping presupposes a *mental model* in that a learner only compares his or her mental models of the two structures but never compares their facts themselves. If the learner cannot compare the mental models, then he or she induces a schema by analogy. In this process, the learner might not be able to define the shared features of the two structures but will definitely be able to aggregate pieces of information or knowledge. To categorize the knowledge, a learner needs to define perceptual and surface-structural as well as deep-structural similarities in a long line of aggregation. For example, in the field of geophysics, the known structure (A) can be mapped to the new structure (B) through the analogical reasoning of structural mapping. Most people rely only on the surface structure of the information rather than its deep structure and thus fail to reach a correct analogical conclusion. Accretion and tuning might also be involved in this process, but a learner does not reorganize or restructure the knowledge at this stage.

In the field of *artificial intelligence* (AI), the agent perceives and models or formulates concepts from its environment and generates an appropriate decision by aggregating different pieces of them in order to construct a solution. Swarup et al. (2006) outlined an extracting ontology from the process of cumulative learning to solve future related problems. Each agent aggregates and accumulates a packet of knowledge that is extracted from solutions to multiple tasks, and these packets impact new learning tasks through analogy (i.e., the agent recognizes and applies similarities between the tasks). Thus, the agents can guide each other's learning process by grounding symbols of the aggregated cumulative knowledge, thereby improving learning performance. As the agent aggregates experiences and builds up its cumulative knowledge to find solutions to new problems, it is expected that more cumulative knowledge will be found (see "► Reinforcement Learning").

Murphy and Medin (1985) argued that a concept is hierarchically related with other concepts as well as structurally related, thus enabling inferences. Accordingly, to ensure an effective and efficient CL, each aggregated concept should be constructively related in the complex knowledge network in order for transfer to be successful in a future learning situation. The packet of collected knowledge should be stored as a composition; otherwise the aggregates would waste limited memory space.

Easterlin (1986) divided the process of concept formation in machine learning into the three following components:

- *Aggregation*, in which important instances of experiences are grouped into a set of aggregates. Here, experiences are aggregated by the learning system itself for further use based on their contribution to a successful problem solution and to system performance.
- *Characterization*, in which a description of the essential information for an aggregate of experiences is generated or constructed in terms of characteristics that are useful to the system based on individual descriptions of each member of the aggregate.
- *Utilization*, in which the concept description is integrated with the performance element of the system and the important aspects of the aggregate are captured.

This process leads to the formation of concepts containing functional information. Then, the agent applies its operators to the subsequent task by mapping objects and operators of current states to consequent states, thus producing a generalized schema with its background knowledge. Again, aggregated experiences, instances, and entities should be characterized and utilized structurally (as stated above) to meet the essential goal of CL.

How can structural aggregation be accomplished? In Pfeffer's (2000) *Integrated Bayesian Agent Language* (IBAL), a learning agent can modify its models based on its collected observations and use them in future situations. He stresses that "a representation language must be modular and extensible" (p. 52) so that the knowledge base can be structurally extended and accumulated. Swarup et al. (2006) suggest starting with small problems with very few easy-to-find solutions to find networks which have subgraphs that can be reused to solve other problems. It seems that chunking the useful aggregated knowledge into a module which can be extended, modified, and dynamically updated is an appropriate means of ensuring the rich process of aggregation for successful CL.

Abstraction

In the process of abstraction, the learner extracts commonalities from superficial features as well as the underlying structure of knowledge and then defines a super-concept of knowledge, identifies underlying relationships, modifies/creates mental model(s), and constructs a new schema by analogy. This new schema can then be applied to the different domains. For example, Edward Hargraves found gold in Australia in 1851 by comparing and finding similarities between the geological characteristics of California and Australia. This abstraction process, however, presupposes a substantial *(re)organization* of learned knowledge. Dörner (1982) has described this aspect of cumulative learning as the "condensation" of an abstract schema by means of a conclusion by analogy. This process involves a search for a known reality domain (as the base of an analogy) which is in certain respects analogous to the unknown target domain. It is in essence a process in which "the concrete aspects of the known stock of knowledge [...] are in a sense 'boiled away' and the remaining 'pure' structure [...] is filled with the concrete aspects of the unknown domain" (Dörner 1982, p. 140). If one accepts Dörner's further argument that this process of abstraction presupposes the existence of a comprehensive system of abstract concepts which allow transitions from one concrete aspect to another, the schema-theoretical argumentation is complete, for which Dörner (1976, pp. 82ff) has defined the following steps:

(a) Abstraction of certain attributes of the phenomenon in question (esp. as regards content);
(b) The search for a model, i.e., for a second phenomenon, which constitutes another concretization of the abstract phenomenon;
(c) Transfer of (structural) attributes of the model back to the original phenomenon; and
(d) A test as to whether the hypothesized attributes are actually present in the phenomenon.

In an extension of this argument, Seel (1991) describes the function of mental models in analogical reasoning: A person makes propositions or predictions for a certain phenomenon (target domain) by falling back on his or her knowledge about similar phenomena (base domain) and creating a mental model for both. On the basis of the structural similarities this person finds between the models of the base and target domains, he or she reaches a conclusion by analogy, integrates both models into a unified solution model under the assumption that they are similar, and tests whether it is possible to create an alternative solution model.

Important Scientific Research and Open Questions

This cumulative effect of learning that results from classification, discrimination, retention, and transfer over a period of time has to be explored extensively in human learning. In the field of human learning, the term CL has not been used explicitly since Gagné (1965). In the fields of machine learning and robotics, on the other hand, CL has been used and studied explicitly in more recent times, and the idea plays an important role. In these fields, a close relationship between CL and schema induction can be found (see Pfeffer 2000). Assuming that CL is the essential concept or mechanism in the process of meaningful transferable learning, bridging the gap between the two fields and learning from the experiences of both seems to be a promising endeavor. The achievement of learning in machines might help us understand how humans learn.

Furthermore, CL and its practical implications for human learning and machine learning should be empirically proven with detailed longitudinal learning research and cross-sectional studies with general learning sequences of large data rather than with peculiar small parts of learning sequences. In that way, it would be possible to explore how learning systems can acquire deeply cumulative knowledge in a long sequence of learning.

Cross-References

- ▶ Abstraction in Mathematics Learning
- ▶ Assimilation Theory of Learning
- ▶ Comprehensive Learning
- ▶ Concept Learning of Humans
- ▶ Concept Mapping
- ▶ Inferential Learning and Reasoning
- ▶ Inferential Theory of Learning
- ▶ Machine Learning
- ▶ Meaningful Verbal Learning
- ▶ Reinforcement Learning
- ▶ Schema-Based Learning
- ▶ Schema-Based Reasoning
- ▶ Schema Development
- ▶ Schema(s)

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Curiosity

Curiosity is a motivational state aroused by certain types of environmental stimuli (e.g., novelty, surprisingness, complexity, ambiguity). These stimuli create a sense of conflict or uncertainty, and these changes in psychological state lead to curiosity. Curiosity encourages a child to explore and become engaged in activities in order to gain new experiences or information.

Cross-References

► Interest-Based Child Participation in Everyday Learning Activities
► Play, Exploration, and Learning

Curiosity About People

► Interpersonal Curiosity

Curiosity and Exploration

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Synonyms

Cognitive curiosity; Diversive exploration; Intrinsic motivation; Sensory curiosity; Specific exploration

Definition

Curiosity is a state of increased arousal response promoted by a stimulus high in uncertainty and lacking in information. When compared to existing knowledge, the novel, uncertain, conflicting, or complex properties of external stimuli create a conceptual conflict that arouses the internal state of arousal called curiosity (Berlyne 1966). Once curiosity has been aroused, the organism engages in a process of exploration to reduce the state of arousal. There are two basic types of curiosity: cognitive and sensory. Cognitive curiosity is the desire for new information, while sensory curiosity is the desire for new sensations and thrills. Exploration entails seeking new information to solve a problem through observation, consultation, and directed thinking (specific exploration) and new sensory experiences and thrills to extend one's knowledge into the unknown (diversive exploration). In a definition that links the two constructs, curiosity is the desire for new information and sensory experiences that motivates exploration of the environment (Reio et al. 2006).

Theoretical Background

Curiosity and exploration have both been linked to animals and humans (Berlyne 1966). Much research has demonstrated that primates, raccoons, rats, birds, dogs, and many other animals seek new stimuli, explore their environment or behave so as to maximize knowledge. As for humans, researchers have associated curiosity and exploration also with cognitive, social, emotional, and spiritual development across the lifespan.

Attachment theorists, for example, acknowledge the link between attachment, curiosity, exploration, and learning. Secure attachment style patterns where an individual feels a positive emotional bond with a parent, teacher, intimate friend, or spouse support safely being curious and exploration of the environment and subsequent learning. Those with anxious-ambivalent and avoidant attachment styles (insecure attachment) are far less likely to be curious and exploratory, particularly when presented with stressful situations, as they are less likely to interact well, explore their environment, and demonstrate emotional resiliency. Therefore, the exploratory and attachment systems work in tandem to promote socioemotional functioning, learning, and development (Voss and Keller 1983).

Psychosocial theorists (e.g., Erikson 1968) and researchers associate curiosity and exploration with identity formation and learning. Identity versus role confusion normatively occurs during adolescence (i.e., it is the central task of adolescence), but is not confined to that period. For adolescents, the confluence of individual internal forces of development (biological), one's unique interests, feelings, and needs, and societal demands to find suitable ways to enter adult roles fosters identity formation. For optimal identity development, however, adolescents must be curious about and explore social roles in the greater community to learn what activities might provide the best fit for one's biological and psychological aptitudes and interests. Thus, adolescents should be willing to be proactively curious and explore the possibilities afforded by their environments to learn how to locate themselves successfully in the larger social order.

Cognitive theorists and researchers, too, embrace curiosity and exploration in their writings. Piaget, for instance, proposed that being proactively curious is a prerequisite for the construction of knowledge because it both stimulates the acquisition of new information and the seeking of new stimuli. In essence, he is referring to both the cognitive and sensory types of curiosity. The information and experiences secured through interaction of the cognitive and sensory types of curiosity and exploration then promote cognitive development through the construction of new knowledge (Reio et al. 2006). Piagetian theory also highlights the role of disequilibration in cognitive development. When an individual is faced with discrepant information, a state of disequilibration is aroused (curiosity) that motivates exploration of the environment for the sake of regaining a state of equilibration. Through this process, new information is acquired, creating conditions for optimal learning and cognitive development.

To be sure, there is a dark side to being curious and exploratory. Cognitive curiosity can be associated with asking too many questions, being meddlesome, and nosy (forms of specific exploration). Sensory curiosity, on the other hand, motivated by the desire for new sensations and thrills despite the risk, is linked to diversive exploration such as drug experimentation, engaging in unprotected sex, and driving while intoxicated, to name a few maladaptive behaviors. Being appropriately curious and exploratory is regulated somewhat by societal and group norms, but when the associated risks outweigh possible gains, it can have profound negative individual, group, and societal implications.

Curiosity and exploration are vital concerns in educational contexts (Flum and Kaplan 2006; Reio et al. 2006). Educators who can arouse their learners' curiosity will improve learner attention, promote greater breadth and depth of exploration of information related to solving a problem, increase time on task, and boost the likelihood that the learners will want to learn more for the sake of learning. Parents also foster curiosity and exploration through modeling it appropriately and embracing both as means to develop the joy of learning in their children. On children's playgrounds, curiosity and exploration are closely linked to both free, imaginative play and games with rules. Through being curious and exploratory during free play, children learn how to productively solve a diverse array of problems related to activities such as building a fort, settling an argument without adult supervision, and soothing an imaginary crying baby when playing house. In games with rules, children need to be proactively curious and exploratory to learn how to play the game in the first place and to find ways to get peers to invite them to join the game. All of these behaviors are conducted in the context of being relatively stress-free where the children learn and develop best cognitively, socially, and emotionally.

Important Scientific Research and Open Questions

Significant theoretical and empirical advances have been made in working out how curiosity and exploration influence learning and healthy human functioning throughout the lifespan. Open questions remain however about the brain systems that support each. A promising "SEEKING," neuroemotional system that encompasses the basic need to seek, investigate, and understand the environment has been receiving increased scholarly attention (Panksepp 1999, p. 145). The SEEKING system runs through the medial forebrain bundle of the lateral hypothalamus where dopamine in particular seems to be an essential ingredient in allowing brain circuitry to operate efficiently. This appetitive motivational system drives and energizes the persistent feelings of curiosity, interest, sensation seeking, the search for higher meaning, and learning beyond the simple promise of rewards. More research is needed to better understand the mechanisms that enable curiosity and exploration through this important motivational system.

Pressures continue to mount for increased academic performance at our schools. High-stakes testing has evolved as a means for assessing, evaluating, and improving the success of school-related activities designed to improve student learning and performance. While arguably laudable, little research has addressed the potential fallout from such activities on student motivation, especially intrinsic motivation like curiosity, exploration, interest, and the like.

Overemphasis on testing may quell students' natural curiosity to learn and have negative long-term consequences.

Cross-References

▶ Adaptation and Learning
▶ Divergent Thinking and Learning
▶ Motivation and Learning
▶ Play, Exploration, and Learning

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Curiosity and Learning

▶ Surprise and Anticipation in Learning

Curious Learning

▶ Anticipatory Learning

Current Concerns

▶ Goals and Goalsetting: Prevention and Treatment of Depression

Curriculum

▶ Alignment of Learning, Teaching, and Assessment

Curriculum and Learning

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Synonyms

Course of study; Plan for learning

Definitions

Stemming from the Latin verb "currere," meaning to run, the noun *curriculum* verbally translates as "racecourse." Historically, the word curriculum has been used to describe the subjects taught during the classical period of Greek civilization. Today, numerous definitions exist for the word curriculum. Hilda Taba in 1962 defines a curriculum as a plan for learning. Her definition permits further elaborations and can be accepted as a brief and foundational interpretation of a curriculum.

Theoretical Background

Introduction

Learning, in the definition of this encyclopedia, takes places in numerous settings. Many of those settings are informal and others are formal. Formal education settings are, for example, primary and secondary schooling, tertiary education, but also some kind of professional development and off-the-job training activities. In formal settings, the provision of learning is usually steered by a plan.

In the educational system of formal school education, a curriculum operates at various levels at which one or more different plans for learning and other curriculum products are in use. At each level, different curriculum and organizational processes take place. A useful distinction of the different operational levels and respective plans for learning and curriculum products are:

- The nano level of the individual student where the processes of individual learning occur and that are steered and supported by personal learning plans and individualized learning courses

- The micro level of the classroom providing the environment and activities for learning, where teaching plans, textbooks, and other teaching materials are used and applied
- The meso level of schools and educational institutions, where educational and school programs are developed and learning environments and learning activities are organized and administered
- The macro level of educational systems and national policies, responsible for the development of core objectives, attainment levels, and examination programs of national curricula
- The supra level of international policies. The supra level influences national curricula and curriculum reform initiatives through multinational comparative studies, for example, PISA and TIMMS, and via international frameworks, for example, the European Reference for Languages. In the context of curriculum development in developing countries, the policies and practices of multinational donors, donor countries, and aid agencies often have implications on all operational levels of the education system within the recipient country.

Curriculum Representations

Further understanding of a curriculum is given by the typology of three so-called curriculum representations that can be detailed into six forms (van den Akker 2003, adapting a distinction of Goodlad 1979). The curriculum representations emphasize the different layers of the curriculum (Table 1).

The so-called hidden curriculum is another terminology in use. The terminology does not originate from the previously introduced concept of curriculum representations. The hidden curriculum refers to the underlying assumptions and beliefs that may not be formally articulated or clearly expressed but that in actual reality are of influence for educational practice.

Curriculum Perspectives

Of the many ways to look at a curriculum, the three perspectives of Goodlad (1994) depict classical angles on curricular issues:

- The substantive perspective, focussing on the archetypical question about what knowledge is of most worth for inclusion in teaching and learning

Curriculum and Learning. Table 1 Typology of curriculum representations

Intended curriculum	Ideal curriculum: referring to the original vision underlying a curriculum, to its basic philosophy
	Formal curriculum: refering to curriculum documents and to curriculum materials such as textbooks, teacher guides, and student materials, also referred to as written curriculum
Implemented curriculum	Perceived curriculum: referring to the curriculum as interpreted by its various users
	Enacted curriculum: referring to the actual instructional processes in classrooms; also referred to as operational curriculum, or curriculum in action
Attained curriculum	Experiental curriculum: referring to the actual learning experiences of students
	Learned curriculum: referring to the resulting learning outcomes of students

- The technical-professional perspective, concerning the methods and practices of curriculum development to successfully translate the intentions in curriculum products to be used for teaching and learning
- The sociopolitical perspective, referring to the influences in the decision-making processes and the different values and interest of different stakeholders

The distinctions are useful for analysis. In practice, all three perspectives come together and are of importance.

In addition to the three perspectives of Goodlad, the critical perspective has established itself in recent decades as an independent variety of curriculum theorizing (Walker 2003). Curriculum criticism is concerned with issues of domination, exploitation, resistance, and what legitimates the knowledge to be taught in the curriculum (Marsh and Willis 1999). Although curriculum critical proponents are not a homogeneous group, Walker (2003) writes that two characteristics unite most of the disparate work. The first is the commitment to view every curriculum as a social construction, and second, the determination to analyze the construction critically to find out how it contributes to the evils of our days.

The Core Curriculum Question of What to Learn

Spanning across all four of the previous perspectives is the core question underlying all curricula and of all curriculum making: “what do we want students to learn, and why”? Or, more elaborated: what are the desirable aims and content of education to equip students for their role in today’s and tomorrow’s society and, intrinsically, how should students learn to acquire the competencies that are identified as necessary? Three main factors influence the answers to these questions. Firstly, new subject specific findings call for being added in the curriculum. In recent decades, this refers especially to the developments in the sciences and in technology. Secondly, to respond to changes in society and emerging challenges, all kinds of societal groups articulate their demands and expectations about what students have to learn, pressing for new content to the included in the overall curriculum. Thirdly, over the past two decades, new understanding about learning has been gained, for example, from developmental psychology as initiated by the work of Piaget and Vygotsky, from cognitive sciences, and also because the overall amount of available knowledge has significantly increased and continues to increase. They have contributed to the scientific development of theories of learning regarding the aims of learning and even more about the how of learning; the attention to diversity in learning styles; and the changes in student and learning environment outside and inside school.

As a result of developments, the question about the what and how of learning continues to occur for curriculum making. Taking up new findings demands for changes in curriculum content and for inclusion of new content. Yet, a curriculum is by its very nature finite. The decision about subject content and learning methods to be included, intrinsically also meaning eliminating other to provide time and space for new ones, is a highly contested area, which is often likened as a battlefield. There are many interests vested in a curriculum and they are addressed by many stakeholders such as pupils, parents, teachers, academics, administrators, economy, labor unions, religious groups, social organizations, and policy makers. Each person has its own educational experience influencing perceptions how education should be shaped; each group has its own experiences, concerns about qualifications and subject-matter insights, and its own consideration and preferences to pedagogical views, political issues, or how society should look like (van den Akker 2003).

Given the complexity of curriculum influences, the selection and out-selection of curriculum content remains an inherently difficult process. Curriculum literature mentions three main criteria for selection and prioritization of aims and content. The three criteria are sometimes referred to as the “three S”:

- Subject, or knowledge: the academic and cultural heritage essential for learning and future development
- Student, or personal development: elements of vital importance from the personal and educational needs of students
- Society, or social preparation: issues relevant for inclusion from the perspective of societal trends and needs.

Quality Criteria for the Learning Potential of Selected Curriculum Content

The learning potential within a curriculum depends on its vertical and horizontal consistency. Vertical curriculum consistency, for example through longitudinal learning trajectories, refers to the buildup and sequencing of learning activities (subject matter, tasks) to link prior learning of students to desired learning and to future learning. Depending on content or learning tasks, the sequencing may be linear, stepped, or spiral.

Horizontal curriculum consistency refers to the coherence between related subject content and methods at one educational level. A horizontally consistent curriculum allows for synergies in teaching and learning activities to supplement each other across subjects and subject combinations.

Curriculum Development

Curriculum development is a process focused on the improvement and innovation of education. Given the definition of this chapter, it relates to curriculum products of any operational levels (see Introduction).

Historically, the creation of curriculum development and the early decades of curriculum development as a field of study were strongly influenced by educators and scientists in the USA. The three most well-known classical approaches and stepping stones to contemporary curriculum development models are Tyler's rational-linear approach, 1949; Walker's naturalistic model, 1971; and Eisner's artistic approach, 1979. The so-called pragmatic approach has more recently come into existence and can be seen as a fourth curriculum development approach. Overarching all approaches are five basic development activities: analysis, design, development, implementation, and evaluation, often abbreviated as ADDIE. In the rational-linear approach, these activities are seen as a linear sequence; in the pragmatic approach the activities are cyclical.

Each of the four curriculum development approaches comprises valuable elements and insights for curriculum development. None of the approaches should be seen as the ultimate model for curriculum construction. None claims to be. This is even more as the tasks and scope of curriculum development at operational levels differ considerably and the number and composition of development teams vary.

Important Scientific Research and Open Questions

The Challenge of Large-Scale Curriculum Implementation

Ideally, the methods and practices of curriculum development are to bridge the intended, implemented, and attained curriculum. Professional literature on curriculum implementation exists, at least, as early as the 1950s. The term implementation became much more in use when several scholars, for example John Goodlad, Neal Gross, and Seymor Sarason, highlighted around 1970 that curriculum innovations in the USA of the 1960s had one fatal flaw, namely, that ideas were not finding their way into classrooms. During the 1970s, numerous studies on the implementation of innovations were undertaken. The Rand study was at that time possibly the most comprehensive research on implementation ever done. It encompassed 293 projects in school districts in different regions of USA. Paul Berman and Milbrey McLaughlin concluded on the findings that successful innovations occurred when planned curricula were not highly specified in advance but were mutually adapted by users within specific institutional settings. Michael Fullan and Alan Pomfret published in 1977 another study. They reviewed 15 major studies in Canada, the United States, and the United Kingdom and found widespread variation in whether or not innovations were being put into practice. Fullan's and Pomfret's use of the two terms *fidelity perspective* and *process perspective* was among the study's greatest influence on researchers. The two studies of Berman and McLaughlin and Fullan and Pomfret have since become highly influential and are widely cited in professional literature on curriculum implementation. They have been followed by numerous studies and research activities of which many concluded that in educational reality, the intended learning of curriculum innovations has rarely taken place. Given those many research findings, the huge gaps between the intentions of a curriculum and what is really learned has become an often-repeated global common theme for which overarching the following major reasons are given:

- Time frames for implementation were much too short (too much was asked in too little time).
- The scope of ambitions was not matched by resources, materials, and organizational and institutional support provided, for example, regarding corresponding professional development of teachers and the time and room for it.
- Ownership of the educational change is critical for success, but often lacking. There are many stakeholders involved in bringing a curriculum into appropriate learning activities to achieve the desired learning. From a systemic perspective, the transport of a national curriculum from the macro level to the nano level faces many challenges. McLaughlin (1998) states that teachers' perspectives on teaching and learning are often rooted in fundamentally different premises of action, if not different goals, than those of policy makers.
- A strict so-called fidelity of implementation approach does not work. It cannot be assumed that top-down introduced curriculum, prescribed by macro level, will be readily accepted and implemented by schools and teachers and students. Firstly, there are as many interpretations of any

curriculum as there are stakeholders (Fullan 2001), and secondly, the transformation of a written curriculum into learning requires substantial adaptations in teacher practices, attitudes, and understanding.
- The meaning of a curriculum was not shared between those who initiated and developed a curriculum and those who were expected to support it and finally put it into classroom practice.

Two major conclusions derive from the findings and have furthered the thinking about curriculum and learning. Firstly, curriculum innovations must fit existing classroom contingencies and ownership of innovations must be shared. Innovations benefit from an analysis about existing issues and requirements of teaching and learning in classrooms and schools. Next to the flow of information from the macro to the micro level, there must also be a reverse communication from micro to macro to address concerns and practical implications of schools and teachers. Secondly, curriculum development requires room for more adaptive implementation to provide for the different contexts and realities of teaching and learning. Formative evaluations at early implementation stages may detect implementation obstacles and thus allow for interventions before hindrances have added up.

Open Questions and Research

Given the complexity of curriculum and learning, there are numerous open questions and research interests. A major focus of recent and ongoing research activities is about how to best enable "educational change" realistically occurring in classrooms and schools. Based on the increased awareness that schools are the place where curricula are transported in learning activities, the question of school development has become a prominent theme of educational change in recent years, also because in many countries educational reforms provide schools with more tasks and responsibility. Subtopics of school development are organization and management at school level, professional development of teachers, and school-based curriculum development.

Another theme of educational change relates to context. The term context refers, especially but not exclusively for reform initiatives in developing countries, firstly, to the supra and macro level and the reciprocal relationship between education on one side and sociopolitical and socioeconomic problems on the other. Context also relates, secondly, to the more educational nano, micro, and meso level of learners, classrooms, and schools. Over the past decades, research has increased understanding about the diversity of educational contexts and its influence on teaching and learning. Within the broad range of research on context, many studies are concerned with questions about the fit between context and curriculum content (subject matter, methods) as well as about the implementation requirements for particular learning and teaching contexts.

Cross-References

► Competency-Based Learning
► Life-Long Learning
► Piaget, Jean (1896–1980)
► Piaget's Learning Theory
► School Climate and Learning
► Vygostky's Philosophy of Learning

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Curriculum Development

► Didactics, Didactic Models and Learning

Customized Learning

▶ Personalized Learning

Customs

▶ Learning and Evolution of Social Norms

Cybernetic Learning Framework

▶ Neurophysiology of Motivated Learning

Cybernetic Principles of Learning

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Synonyms

Constructivist learning principles; Feedback systems in learning; Learning as effective action

Definition

The cybernetic principles of learning are drawn from the implications of applying to learning the insights into the behavior of living systems provided by the study of cybernetics. Cybernetics is underpinned by the notion of circularity and feedback between a system and its environment. Maturana and Varela (1987) say that both a living system and an environment are structurally determined and therefore, through recurrent interactions and feedback, both will change congruently according to their structure as they interact, each contributing to the creation of the world by living in it. This process they call ▶ co-ontogenic structural drift. The change that occurs through this process they call *learning*. Rather than knowledge being something static that is taken in from the outside by the senses and stored somewhere, it is a process of *knowing* that results from minute-by-minute accommodation of system and environment as each adapts and survives. Because each living system is structurally different, each living system will distinguish different information in its environment as relevant to its survival. This information is what Bateson (1972) calls "a difference which makes a difference" (p. 381). Just what difference (i.e., what stands out from the background of "environment") a living system takes notice of depends on the living system's life-time history of interactions that have made it what it is. Learning as survival means that whatever learning occurs will manifest in effective action that enables the system to go on living. Thus, some key principles of learning that can be drawn from these insights include:

- Learning is a survival strategy.
- Learning is living, it is a continuation of life history, fitting with what has gone before and in some way anticipated.
- Learning is triggered by the environment; there are no direct inputs of information through the senses for storage in the brain.
- The environment and communication as part of the environment form the living/learning connection for every living system.
- Learning is diffused, idiosyncratic, continues over time as part of life, and from an observer's perspective, it may be only loosely connected with any program of study.

Theoretical Background

The term *cybernetics*, coined by the mathematician Norbert Wiener in 1947, comes from the Greek *kubernetes* meaning helmsman or steersman, which is also where we get the word *governor*, meaning a feedback device that controls a machine's speed. Wiener chose the word *cybernetics* because of its connotations of steering and control and their implied reliance on information, communication, and feedback in order to be effective. Although applied by Wiener to steering and control in animal and machine, the term has since come to mean the study of how all kinds of systems behave and includes the notion that the observer is also part of the system – an innovation that was originally known as *second-order cybernetics* but is now recognized simply as *cybernetics* with Wiener's original meaning becoming a subset of the expanded meaning.

Unlike previous theories of machines Wiener's breakthrough was, according to Ashby (1957), to shift the question from one about the nature of mechanical *things* (what is this?) to one about *ways of behaving* (what does this do?). Wiener's science of control and communication saw the transmission of an unambiguous message as an engineering problem (as did Shannon's 1949 Information Theory) where feedback governed changes in communication, which changed behavior, which changed the communication and so on in a circular feedback loop that enabled a system to maintain a desired state. Hence, cybernetics originally had a close association with physics. However, because it deals with all forms of behavior, it is no longer confined to that field of study. In fact, Ashby (1957) saw it as providing a common language and set of concepts capable of illuminating the behavior of *complex systems* wherever they occur including machines, brains, and society. He suggests that the *system* should be treated as though it were a black box with the experimenter or observer seeking patterns that link the black box inputs to its outputs. By ignoring the contents of the box (what is this *thing*) and instead concentrating on acting on the box in some way (input) and observing what happens (output), the experimenter has no need to open the box. Instead, the observer's role is to discern *patterns in behavior* that link inputs to outputs.

This focus on behavior and the use of the black box device has linked cybernetics to Skinner's behaviorist psychology (e.g., Skinner 1989). Skinner saw the brain as a black box with inputs in the shape of rewards or punishments and outputs conditioned by those inputs. Thus, according to Skinner, behavior could be modified and controlled and "learned behavior" could be objectively studied. Although this may be close to the original engineering approach to cybernetics, most cyberneticians have for a long time seen cybernetics as far from a linear input–output model. In a major departure from Skinner's mechanistic idea of behavior, Ashby includes the role of the experimenter in the experiment. This, as Glanville (2009) points out, indicates that Ashby already understood what became known later as second-order cybernetics – the meta-study of box plus investigator studying the box.

In his collected writings from the journal *Cybernetics and Human Knowing*, Glanville (2009) recognizes Ashby as one of a handful of scholars who wrote extensively and seriously about the Black Box. Glanville himself is another. He extends the use of the Black Box as a way of understanding how we learn about the world. We cannot know what is inside (i.e., what is "real"), but we build a model of how the world works as we interact with the Box and observe the "output." However, no matter how well our model stands up, we can never say that it is a true representation, because we can never look inside the Box. And no matter how objective we try to be in our observations, any observation is a transaction between Black Box and observer. This is a radical constructivist position. Constructivism is based on the understanding that knowledge is constructed by the learner as s/he interacts with the world. Von Glasersfeld's radical constructivism says that we can neither confirm nor reject an external absolute reality. We operate on hypotheses and only revise them when they no longer fit with our experience (von Glasersfeld 2007). In this respect, cybernetics has strong links with the work of Piaget (1897–1980) who was originally a zoologist. His work describes how children build up a picture of the world through making their own sense of inputs to the black box of the mind, converting experience to a personal understanding of concrete objects. For Piaget knowledge thus built did not provide a "true" picture of an absolute reality but provided a working model that contributed toward the organism's equilibrium.

In this view of how we develop understanding, no one can be the controller sitting outside the system pulling levers and knowing exactly what the message (output) is supposed to be. The message is not transferred unambiguously through some machine (or Black Box, which could be a mind/brain), but instead meanings are constantly being negotiated. This is the experimenter, or in the words of von Foerster (1992), *the observer*, being both an observing system (observing the input to and output from the Black Box) and also part of a larger system (observer plus box) observed by another which in turn is observed by another and so on with always yet another system engulfing the observed system and the observer. This is the observing of observing the cybernetics of cybernetics.

The term *cybernetics of cybernetics* (or second-order cybernetics) was first used by Margaret Mead in a paper written in 1968. However, Glanville argues that Mead and Bateson (1972) had probably always understood cybernetics in these second-order terms. He bases this insight on their input into the Macy conferences, chaired by psychiatrist Warren McCulloch and held in New York between 1946 and 1953, which brought together the anthropological observations of Bateson and Mead with for example, the fields of digital computing and neurophysiology. These conferences grappled with the notions of feedback and circular systems. In 1949, when the physicist von Foerster joined the group, the problem of *the observer* was raised sparking a debate about whether meaning is an intrinsic component of information or something attributed to the observer and thus different for everyone. This shifted the focus of cybernetics from an engineering problem to one of accounting for behavior in biological and social systems.

Biologists Humberto Maturana and Francisco Varela (1987) continued this shift. They argued that knowledge cannot reflect an ontological world but instead should be judged by effective action in the experiential world – effective, that is, from the perspective of the actor who makes decisions on such effectiveness out of personal experience and survival needs. Hence, the central notion of circularity is here applied to living systems that can only know the world out of their own construction of meaning from their experiences – which knowing then becomes part of who they are, constituting the self that constructs meaning from experience and so on. In this case, "knowing" rather than "knowledge" is the important word, denoting a process rather than some idea of a fixed and knowable world.

Maturana and Varela (1987) provide a biological explanation for this process of knowing. They equate learning with change and say that learning happens to us as we adapt and survive. The particular change/learning depends on who we are (which depends on the body we were born with and its history of interactions) and the environment with which we interact through communication, which they call ► languaging and emotioning. Thus, learning cannot be stored as knowledge in the brain but is a process of going on living in an environment changing and being changed by it. To go on living is to go on learning; learning is surviving – a reciprocal dynamic process between living system and environment (which includes other living systems and all communication) in which changes in one trigger changes in the other. Maturana and Varela (1987) say that we bring forth the world by living in it. In this respect, they diverge from radical constructivism, which says that there may or may not be a reality "out there" but if there is we can only ever know what it is not, revising our hypotheses whenever we bump up against it and our current hypotheses do not fit.

Important Scientific Research and Open Questions

In his musings on the current state of cybernetics, Glanville (2009) says that it was at one time considered to be the new super-science. It generated great excitement and was seen as relevant, for example, to physics, biology, social science, engineering as well as philosophy, anthropology, and neurophysiology. It was appropriated into the world of artificial intelligence and bionics from where it reappeared in the form of systems theory, by which time, the excitement around cybernetics itself had died thus leaving systems theory to take center stage. Glanville puts this fading of cybernetics as an area of study down to its success in providing valuable tools for use in such a huge range of other disciplines. He suggests that cybernetics itself has practically disappeared and the origin of these tools has been forgotten. Heinz von Foerster, who died in 2002 and to whom volume 10 (no. 3–4) of *Cybernetics and Human Knowing* was dedicated, saw this differently. He believed that far from dead, cybernetics acts implicitly and powerfully across many facets of life today, particularly its central notion of feedback, which is widely known and used.

However, there are areas in which the field of cybernetics continues to grow. Within its framework, several areas of research have opened up. Glanville continues to write extensively on the Black Box and its usefulness in understanding learning. Sociocybernetics has become an established field of study with a dedicated journal that explores systems science in the social sciences and combines systems theory and cybernetics. And cybersemiotics has been established through the work of Søren Brier, who in 1992 founded the journal *Cybernetics and Human Knowing*, which now covers not only second-order cybernetics but also ► autopoiesis and cybersemiotics. Cybersemiotics is a transdisciplinary framework that brings together semiotics and second-order cybernetics with cognitive semantics, language game theory, and Niklas

Luhmann's social systems in which Luhmann sees social systems as self-organizing. He applies Maturana and Verela's theory of autopoiesis to the way in which social systems communicate and learn, something with which Maturana himself is not entirely comfortable.

Cross-References

► A Salience Theory of Learning
► Bateson, Gregory (1904–1980): Anthropology of Learning
► Constructivist Learning
► Double-Loop Learning
► Embodied Cognition
► Piaget's Learning Theory

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