found that as new hidden units were generated, the network reached stage four on the balance scale task.

Shultz proposes that while networks with a fixed architecture learn by a process comparable to rote memorization, dynamic networks "grow" new units and connections and are thus able to actively reorganize what is being learned. Walter Schneider and David Graham (1992) suggest that traditional classroom learning can benefit from this research by exploiting both styles or modes: conventional memorization-based learning, balanced with self-directed or problem-based learning.

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CONSTRUCTIVISM

This entry contains the following:

OVERVIEW

The term constructivism has played a dominant role in educational literature for a number of decades. While educators generally agree on several core aspects of constructivism, significantly different interpretations, perspectives, and approaches exist regarding the details of constructivist learning and teaching. This section discusses (a) the historical roots of constructivism, (b) perspectives on constructivism as epistemological theory, learning theory, and pedagogy; (c) the continuum of constructivist perspectives from individual to social, (d) evidence for the efficacy and adoption of constructivism, (e) the key assumptions about constructivist learning and instruction, and (f) introductions to several instructional approaches involving constructivist designs.

HISTORICAL ROOTS OF CONSTRUCTIVISM

Constructivism, although relatively new in its current form, has deep historical roots. At their core, constructivist perspectives focus on how learners construct their own understanding. Some philosophers, such as Socrates, focused on helping students construct meanings on their own rather than having authority figures transmit information to them. Immanuel Kant (1724–1804) built upon this by recognizing that the way learners perceive stimuli from their environment shapes their understanding of the world. In the early 20th century, John Dewey (1859–1952) proposed that education should work with students' current understanding, taking into account their prior ideas and interests. Later, Jean Piaget (1896–1980) defined accommodation and assimilation as ways for new knowledge to build upon previous knowledge. The ideas of Lev Vygotsky (1896–1934) also influenced constructivism. He helped increase awareness of the interactions between the individual, interpersonal, and cultural historical factors that affect learning.

CONSTRUCTIVISM AS EPISTEMOLOGICAL THEORY, LEARNING THEORY, AND PEDAGOGY

The term constructivism can refer to one of many different but related concepts. More specifically, constructivist perspectives can focus on epistemological theory, learning theory, and pedagogy.

As an epistemological theory, constructivism focuses on how bodies of knowledge come to be. This perspective is important to note even though this view of constructivism is not discussed in the educational literature as frequently as other views. Constructivism as an epistemological theory holds that disciplines, such as history and mathematics, are constructed by human interactions

and decisions. For some disciplines, such as literature, this idea is fairly well accepted; there are certain books that most people agree are worth reading and others that are purposefully forgotten. For disciplines such as science and mathematics, however, the idea that people (and not nature) construct the bounds of the disciplines and the concepts within them remains contentious.

More commonly, educators view constructivism as a learning theory. Some educators use the term constructivist simply to indicate a non-behaviorist learning theory. While constructivist learning theories are non-behaviorist, constructivism involves much more than simple opposition to a previous learning theory. From the perspective of constructivism, learners construct knowledge based on what they already understand as they make connections between new information and old information. Students' prior ideas, experiences, and knowledge interact with new experiences and their interpretations of the environment around them. Research by Savery & Duffy (1995) suggests that learning how to use constructivist theories involves many interactions between the content, the context, the activity of the learner, and the goals of the learner.

Cognitive conflict drives this knowledge-building process. Cognitive conflict occurs for learners when they encounter and recognize discrepancies between what they already know and new persuasive information that brings their current understanding into question. These discrepancies cause cognitive tension requiring adjustment to reduce the discrepancies. When students resolve these discrepancies they actively figure out ways to reconcile their prior knowledge or understanding with the new information. Students may construct new knowledge from pieces of prior knowledge or restructure prior knowledge. Thus the resolution of cognitive conflict drives learning.

Finally, based on the core ideas of constructivist learning theory, constructivist pedagogy proposes that instruction must take students' prior ideas, experiences, and knowledge into account while providing opportunities for students to construct new understanding. Constructivist pedagogies are discussed in greater detail below, in the sections titled Assumptions about Constructivist Learning and Instruction, and Instructional approaches with constructivist designs.

CONSTRUCTIVIST PERSPECTIVES FROM INDIVIDUAL TO SOCIAL

While the general principles discussed above apply to most constructivist theories and pedagogies, significantly different interpretations have evolved regarding the details. One key distinction, discussed by Phillips (2000) and other educators, among constructivist perspectives involves the continuum of interpretations in terms of where the construction of knowledge takes place. Radical constructivism anchors one end of this continuum and social constructivism anchors the other. Most educators' theoretical commitments fall somewhere between these two perspectives.

RADICAL CONSTRUCTIVISM

Radical constructivism proposes that the construction of knowledge takes place solely in the learner's mind and on an individual level. Ernst von Glasersfeld (1917–) refined many of the core ideas of radical constructivism. McCarty and Schwandt (2000) explain that according to radical constructivism, concepts form through the learner's experiences with objects or events as the learner notes similarities and differences among the experiences and gradually builds up a concept relating to that object or event.

Radical constructivism is similar in many ways to Jean Piaget's perspectives on assimilation and accommodation and to theories of information processing. Both Piagetian and information processing theories view learning as a cognitive activity through which individuals actively incorporate new information and experiences into the information and understandings already stored in memory. Piaget explains these processes in terms of assimilation, in which learners add new information into their existing knowledge frameworks, and accommodation, in which the new information causes cognitive conflict that results in the reorganization of learners' knowledge frameworks. Information processing theory uses a computer metaphor to explain how knowledge construction works. The learner perceives various stimuli, encodes them into useful information, and then stores the information for later use. The learner is able to modify previous knowledge or strategies in order to help with current problem solving and develop more sophisticated knowledge. In alignment with radical constructivist perspectives, therefore, both perspectives focus on how the individual processes and relates new information to information already in the mind.

Radical constructivism holds serious implications for learning and teaching. Most importantly, from the perspective of radical constructivism, a person cannot ascertain that what other people have constructed in their minds is exactly the same as what he or she has constructed. In spite of this paradox, teachers must act "as if there were a world about which meanings were shared" (Howe & Berv, 2000, p. 33).

SOCIAL CONSTRUCTIVISM

Social constructivism represents the other end of the continuum. Social constructivism, heavily influenced by Vygotsky and sociocultural theory, proposes that learning takes place in the interaction between people and their

CONTROVERSY OVER THE EFFICACY OF CONSTRUCTIVISM

While significant evidence supports the efficacy of constructivist approaches, other evidence suggests that other forms of instruction offer important advantages depending on context. Research by Kirschner, Sweller, and Clark, for example, suggests that many constructivist-based approaches do not work as well as direct instruction in changing long-term memory. Part of their argument hinges on findings from cognitive science that limit the amount of information that can exist in working memory at one time. In addition, constructivist methods commonly involve problem solving situations where the learning is self-directed, which unchecked can lead to potential misconceptions. Furthermore, research by Elby suggests that different theoretical views about what misconceptions are (either stable entities or cued responses based on context) lead to dramatically different student outcomes. Teachers who are able to recognize productive elements in students' intuitive understanding may be more successful in constructive pedagogies. A further issue limiting the efficacy of constructivist approaches involves the fact that many teachers have not received sufficient training to effectively support their students in constructivist learning activities. More research on the efficacy of constructivism would be useful and would help educators focus on specific pedagogical methods and the limitations and advantages of each.

environment. An extreme social constructivist view developed by Kenneth Gergen proposes no strict boundary between the mind and the environment or between language and reality. This view further proposes that a person's understanding of the world cannot be removed from the way he or she uses language to describe it, view it, and discuss it with others.

Less extreme social constructivist perspectives propose simply that students construct knowledge through an interaction with their surroundings rather than in isolation from them. Social interactions play an important part in knowledge construction because they support the introduction and resolution for the cognitive conflict at the heart of constructivist learning perspectives. Although moderate social perspectives acknowledge the role of people's prior knowledge in the evolution of their understanding, moderate perspectives propose that knowledge structures evolve socially through observation and interaction with other people and the environment. Sociocultural theories and perspectives emphasize the importance of learners' interactions with their social environment in order to determine what should be learned and how it should be learned. Also, being able to discuss developing ideas with others helps learners determine how to modify their ideas.

Different flavors of social constructivism have different emphases for learning and instruction. Some emphasize cognitive skills and strategies for learning while others emphasize the big ideas or concepts in a discipline. Some social constructivists propose three fundamental commitments for teaching and learning: treat the discipline with respect, treat students' ideas with respect, and view the discipline as a "collective intellectual endeavor situated within a community" (Ball & Bass, 2000, p. 197). From this perspective, instruction should involve a democratic process in which students and the teacher discuss what represents publicly shared knowledge and what does not. Instruction should focus on this publicly shared knowledge in order to allow all the students to build upon what they know and to help the teacher understand what steps need to be taken in order to achieve certain goals.

EFFICACY AND ADOPTION OF CONSTRUCTIVISM

Constructivist teaching, introduced by Piaget in the early 1930s, has found increasingly wide acceptance by researchers and educators since the early 1980s. Although widely accepted, however, constructivism remains less widely practiced. A study by Moussiaux and Norman (1997) involving 49 schools and 289 teachers in Michigan found that only 28% to 50% of teachers claimed to use constructivist methods. Furthermore, as noted by Jones and Carter (2007), many teachers who believe they enact constructivist methods do not actually use methods in alignment with constructivist theories. Teachers should be aware of not just the instructional strategies they are implementing but also the theoretical reasons behind those strategies and how they can be used in different ways. Abbott and Fouts found that only 17% of 669 classrooms in 34 schools in Washington actually incorporated constructivism into instruction.

Barron and colleagues (1998) suggest that constructivist approaches remain underimplemented and underutilized because constructivist teaching practices are foreign to students and teachers, and difficult to apply. Many people in the general public remain suspicious when teaching methods differ from the forms of instruction they experienced in school. High-stakes testing represents

another obstacle to wider implementation of constructivist instruction. Although state education standards usually include constructivist goals, these standards and goals often do not align with the high-stakes tests or the preparation for those tests. A review by Jones and Carter (2007) suggested that wider implementation of constructivist approaches will require changes in teacher attitudes and beliefs in addition to educational reform.

While authentic constructivist pedagogies remain relatively uncommon in classrooms, many studies support the potential efficacy of constructivist approaches. Abbot and Fouts (2003), for example, found a significant correlation between constructivist teaching and higher achievement. Different constructivist approaches appear, however, to vary in their levels of efficacy. Research on guided discovery learning and pure discovery learning demonstrates that students engaging in guided discovery learning activities outperform students in pure discovery curricula (Shulman & Keisler (1966), Kittel (1957), and Mayer (2004)). In summary, studies have shown that constructivist approaches have great potential but require authentic implementation in order to achieve that potential.

ASSUMPTIONS ABOUT CONSTRUCTIVIST LEARNING AND INSTRUCTION

Although constructivist instruction can take many forms based on the instructor's theoretical commitments, constructivist teaching at its core focuses on students' active role in their own learning as they build and organize their knowledge. Constructivist instructional frameworks, such as those discussed by Lebow (1993), often focus on the following attributes: personal relevance, the opportunity to generate new knowledge, personal autonomy, active engagement, collaboration, the opportunity to reflect on learning, and pluralism. In addition, Langer and Applebee (1987) discuss how the core goals of constructivist teaching often include promoting democratic learning environments and student-centered instruction. As a result, "teachers are apt to feel comfortable in this role only if they view uncertainty and conflict as natural and potentially growth producing for members of the learning community" (Prawat & Floden, 1994, p. 40).

To create personal relevance, learners need to understand the benefits and importance of the curriculum for their own interests. Teachers can promote this relevance by incorporating real-life situations and experiences into their students' classroom learning. To give students an opportunity to be involved in creating knowledge, the learner should be involved not in activities in which the goal is to memorize facts but in problem-solving activities. For instructional design geared toward radical constructivism, students should be provided with personal autonomy in which individual work is part of the instructional framework. Also, students should be part of the process of designing the problem as well as dictating the process for working on that problem. Furthermore, to actively engage students, "the teacher's role should be to challenge the learner's thinking—not to dictate or attempt to proceduralize that thinking" (Savery & Duffy, 2001, p. 5). For instruction geared toward social constructivism, collaboration provides opportunities for students to interact and teach one another in small group work.

INSTRUCTIONAL APPROACHES WITH CONSTRUCTIVIST DESIGNS

While many pedagogical approaches integrate key constructivist assumptions about learning and instruction discussed above, five approaches currently receive significant attention. These include (a) case-based learning, (b) discovery learning, (c) inquiry-based learning, (d) problem-based learning, and (e) project-based learning.

Case-based learning, as Herreid (1997) explains, uses real-life examples to build knowledge by resolving questions about a specific case. Usually these questions have no single right answer. Generally, case-based learning focuses on small groups and the interactions between the participants. The teacher facilitates the students' interactions while the students choose analysis techniques and work toward solutions of the open-ended problem. Under this pedagogical approach, students learn content while exposed to real-life issues. Students benefit from this type of instruction because they are given an opportunity for decision making as part of their learning process and because they experience and address different viewpoints.

Discovery learning engages learners in problem solving to make a discovery, as described by Mayer (2004). According to Seymour Papert, "The role of the teacher is to create the conditions for invention rather than provide ready-made knowledge" (Papert, 1980). The instructional design of discovery learning provides students with a problem and the opportunity for exploration to formulate solutions to the problem. The teacher guides the development of problem-solving skills and the creativity of the students. Discovery learning works on the assumption that students are more likely to retain knowledge if they discover it on their own. Students benefit from this type of instruction because it fosters curiosity and creativity.

As discussed by Edelson, Gordin, and Pea (1999), inquiry-based learning places the responsibility for learning and understanding concepts on the student. In other words, inquiry learning requires students to determine the content, the learning process, and the assessment of

learning. Inquiry-based methods use questions to guide instruction rather than predetermined topics. Usually this instructional design begins with a general theme that serves as a starting point for learning. Then the instruction builds upon the responses and interactions of the students. Teachers monitor the students' learning process through interviews, journaling, and group discussions. Students benefit from this instructional approach because they develop meta-cognitive learning skills and research skills upon which they can build toward future educational experiences.

Similar to case-based learning, problem-based learning teaches students to think critically, analyze problems, and use appropriate resources to solve real-life problems. Through this process, students identify the nature of the problem and determine what resources they need to utilize to solve the problem, as described by Boud & Feletti (1997). The teacher offers scaffolding by providing examples of how to approach the problem. A study by Wood (1993) suggests that students benefit as they integrate analytical skills with content knowledge as a member of a team.

Project-based learning also harnesses the process of investigation to encourage understanding. This method, as described by Polman (2000), engages students in a long-term project based on a real-life problem. These activities typically involve a wide range of interdisciplinary skills, including math, language, art, geography, science, and technology. This instructional design has less structure than traditional instruction because the students organize their own work. Generally, this approach involves collaborative learning. The teacher provides guidelines (such as checklists) for the students as they progress toward the completion of their project. By providing students with an authentic problem, project-based learning offers students a meaningful experience that promotes the development of research skills.

SEE ALSO *Cognitive Development: Piaget's Theory; Information Processing Theory; Sociocultural Theory.*

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CASE-BASED LEARNING

Case-based instructional methods are used in a variety of disciplines, including medicine, law, business, and education. Cases provide analogs of personal experience; they include a representation of a situation, how the situation was dealt with, and what the consequences were of dealing with it in that way (Kolodner, 1997). Cases describe an interesting story that will generate alternative perspectives from learners. Cases should provoke alternative ideas and require decision making (Herreid, 2008). There are a variety of methods for using cases in the context of instruction. Collaborative discussions among students about the case are common. Students are expected to bring their knowledge and perspectives to the consideration of the case, engage in argumentation about the interpretation of the case with their peers, and deepen their understanding of the issues at hand. In doing so, students use their prior experiences and knowledge to construct new knowledge and understandings.

The various disciplines that use cases as part of their instruction vary in how they define cases. It is difficult to distinguish a case from an example or a problem. Cases are used in various disciplines for different functions. In law schools, students study cases from the past and learn to use them as examples of judicial reasoning (Herreid, 2008). In medicine, cases are examples of previous medical decision making. In both law and medicine, the consequences of the particular decisions made are clear. In education, cases are used in preservice teacher education to illustrate theoretical ideas or to practice decision making. However, the consequences of one set of actions rather than another are much less clear in education than in other domains.

The use of cases in teacher education has the potential to bridge the gap between the declarative knowledge acquired in coursework and the procedural and conditional knowledge developed through practice. Many of the writings available about cases appeal to this potential (e.g., Doyle, 1990; Shulman, 1992). Because cases (e.g., a particular problem in a teacher's class) have face validity as representations of classrooms, teaching by using cases is often touted as a preferred teaching method (Silverman, Welty, & Clark, 1996). However, in 1996 K. K. Merseth noted: "the collective voice of its proponents [the use of cases] far outweighs the power of existing empirical work" (p. 722).

The use of cases for instruction also has the potential to provide a window on developing expertise. More and less experienced individuals can be expected to respond to cases in different ways, providing instructors with insight into how cases are understood. There is some evidence that the use of cases can result in the development of theoretical and practical knowledge (Lundeberg, Levin, & Harrington, 1999). Case discussions can promote reflection and metacognition (Harrington, 1995; Levin, 1995). Much of the research on the use of cases in teacher education has been conducted within the context of college classrooms, and the designs of such research are typically pre- and posttest designs within specific courses that show an increase in the number and kind of theoretical constructs included in the posttest case analysis. Although this kind of research has yielded useful and important information, it is unclear whether the effects are due to the case method *per se* or simply to the exposure to the content of the course. Lundeberg and colleagues (1999) and Levin (1995) call for more systematic research on the use of cases in teacher education.

Students vary in their responses to case-based instruction. In a small study of nine veterinary students, students who had high levels of self-regulatory skills perceived the format of the instruction to be relevant and effective, whereas those students with low self-regulatory skills did not (Ertmer, Newman, & MacDougall, 1996). The degree to which participants engage in discussions related to a case also influences the quality of their thinking about the case (Levin, 1995).

The research on the use of cases has not been programmatic nor are the results systematically organized. It is difficult to draw conclusions about the effectiveness of case-based instruction and learning when there are different criteria across disciplines for what constitutes a good case, how effectiveness is assessed, and how research is conceptualized.

SEE ALSO *Cognitive Apprenticeship; Scaffolding.*

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