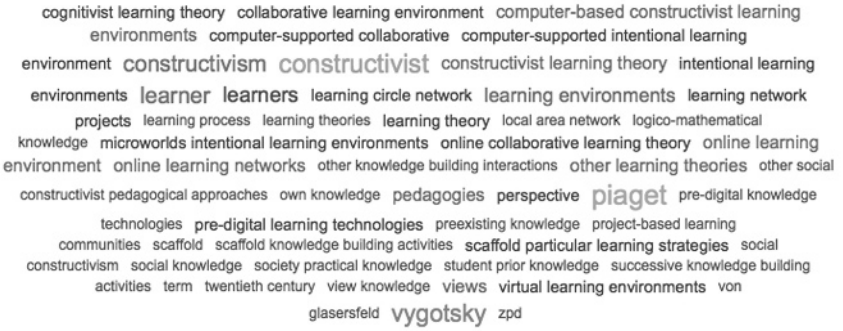
5
Constructivist Learning Theory

In hindsight, the reason for my students' poor performance is simple. The traditional approach to teaching reduces education to a transfer of information … However, education is so much more than just information transfer, especially in science. New information needs to be connected to pre-existing knowledge in the student's mind. Students need to develop models to see how science works. Instead, my students were relying on rote memorization. Reflecting on my own education, I believe that I also often relied on rote memorization. Information transmitted in lectures stayed in my brain until I had to draw upon it for an exam. I once heard somebody describe the lecture method as a process whereby the lecture notes of the instructor get transferred to the notebooks of the students without passing through the brains of either. That is essentially what is happening in classrooms around the globe.

—Eric Mazur, 2009



Chapter 5 will cover the following topics:

- Context of constructivism
- Constructivist learning theory and major thinkers
  - Piaget: developmental constructivism
  - Vygotsky: social constructivism
- Constructivist learning pedagogy
  - Active and authentic learning
  - Learning-by-doing

  - Scaffolded learning
  - Collaboration
- Constructivist learning technology
  - Construction kits and microworlds
  - Scaffolded knowledge-building environments
  - Telecollaboration
  - Online course delivery.

Context of Constructivism

Constructivism refers to a theory or set of theories about learning that emerged in Europe and were introduced to the United States around the 1970s, during a period of social reform and civil rights movements and challenges to the "old" order and its hierarchies. The social movements had a strong impact on education. Moreover, cognitivist views came under criticism. Educational researchers and practitioners began to reject the notion that humans could be programmed like robots, to always respond in the same way to a stimulus. In fact, it became recognized that the mind plays an enormous role in how people act when learning. But that role is not directly comparable to a software program based on discrete steps to consume and process information as put forward by cognitivist theorists. Constructivism—particularly in its "social" forms—suggests that the learner is much more actively involved in a joint enterprise with the teacher and peers in creating (constructing) knowledge.

Constructivist Learning Theory

Constructivism refers both to a learning theory (how people learn) and to an epistemology of learning (what is the nature of knowledge). Both the constructivist theory of learning and constructivist epistemology are generally quite distinct from behaviorism and cognitivist theories of learning, although some theorists are associated with more than one of these theories. Moreover, the constructivist epistemology is reflected in other learning theories, not only constructivist theory. Thus it is important to keep in mind that the term constructivism is used in two distinct ways, to refer to a theory and to an epistemology.

Constructivist theory posits that people construct their own understanding and knowledge of the world through experiencing the world, and reflecting on those experiences. Our encounters with new ideas, new things and new perspectives require that we reconcile the new with our prior understanding: does the new fit with our previous understanding and if not, do we discard it, integrate it with our existing views or change our existing beliefs? This process is one of asking questions, exploring, engaging in dialogue with others and reassessing what we know. As such we are active creators and constructors of our own knowledge.

Moreover, as discussed in Chapter 1, the constructivist epistemology, regarding what is knowledge, is very distinct from the objectivist epistemology that underlies behaviorist and cognitivist theory. In the constructivist perspective, knowledge is constructed by the individual through his or her interactions with the community and the environment. Knowledge is thus viewed as dynamic and changing, constructed and negotiated socially, rather than something absolute and finite. This has important implications for teaching and learning, and will be explored further in the section on Constructivist Pedagogy.

Constructivist learning theory, like behaviorist and cognitive learning theories, is not one unified entity. Rather it is an umbrella term representing a range of perspectives based on two or more rather distinct positions while sharing some common denominators. Duffy and Cunningham (1996) clarify the basis of constructivism, noting that despite the diversity of views encompassed in the concept of constructivist learning theory, there seems to be a general consen-

sus to the general view that "learning is an active process of constructing rather than acquiring knowledge," and that "instruction is a process of supporting that construction rather than communicating knowledge" (p. 177).

In the 20th century, the major theorists associated with constructivist approaches were Jean Piaget and Lev Semyonovich Vygotsky. Two major camps or perspectives are associated with constructivism, one with each theorist:

- "cognitive constructivism" is how the individual learner understands the world, in terms of biological developmental stages; and
- "social constructivism" emphasizes how meanings and understandings grow out of social encounters.

Cognitive constructivism focuses on the individual learner and emerged from the thinking and research by Piaget. Social constructivism emerged from the work of Vygotsky and emphasizes the social essence of knowledge construction.

Piaget

Jean Piaget (1896–1980), a Swiss-born professor of psychology and student of biology, devoted his life to the question of cognitive development, and particularly to classifying the stages of human development. Piaget posited that humans learn through the construction of progressively complex logical structures, from infancy through to adulthood. Humans, in his view, learn through the construction of one logical structure after another. Piaget also concluded that the logic of children and their modes of thinking are initially entirely different from those of adults, and that successive knowledge-building activities increase in depth and complexity as humans move from one stage to another in their development: age-based stages. Learning followed development: it occurred according to the child's age and stage of development. Development ceases as the child reaches early adulthood, according to Piaget's four stages of development, and Piaget did not discuss adult learning.

Piaget was not only a psychologist but also a biologist. He strongly defended and promoted the scientific method, and he believed that the scientific approach was the only valid way of gaining access to knowledge. This conviction influenced Piaget's perspectives on psychology, and led him to declare: "This made me decide to devote my life to the biological explanation of knowledge" (Munari, 1994). Munari, who collaborated with Piaget from 1964 to 1974, wrote of Piaget that

> With regard to his work as a researcher and university teacher, the constant concern influencing and guiding his work and, indeed, his entire life was that of winning recognition, especially by his colleagues in physics and the natural sciences, for the equally *scientific* nature of the human sciences and, more specifically, of psychology and epistemology. His attitude and his involvement in the field of education led him quite naturally to champion the pupil's active participation as the royal road to the scientific approach in school. (Munari, 1994)

Piaget is also identified with genetic epistemology or genetic constructivism, what he referred to as "a kind of embryology of intelligence" (cited in Munari, 1994). As Munari notes,

> In particular, the basic postulate of genetic psycho-epistemology whereby the explanation of all phenomena, whether physical or social, is to be sought in one's own mental development and nowhere else, helped to give the historical dimension a new role, in teaching methods as well as in general debate on education. Every theory, concept or object created by a person was once a strategy, an action, an act.

Piaget's concept of genetic epistemology reflects the span of his interest in the areas of biology, philosophy and child psychology, all related to how the child comes to know his or her world. Genetic epistemology reflects Piaget's work in studying knowledge and, in particular, the origins or genesis of knowledge, and reflects his interest in both the philosophy (epistemology) and psychology of knowledge.

George Bodner, professor of chemistry, whose 1986 article "Constructivism: A Theory of Knowledge" examines the use of constructivism in the classroom, noted:

> Piaget believed that knowledge is acquired as the result of a life-long constructive process in which we try to organize, structure, and restructure our experiences in light of existing schemes of thought, and thereby gradually modify and expand these schemes. (p. 875)

Bodner quotes a passage from Piaget (1968) in which Piaget describes the period between birth and the acquisition of language as a mini-revolution; a Copernican revolution in our personal universe, as our understanding develops from total self-centeredness to being a participant in a social universe.

> At eighteen months or two years this "sensorimotor assimilation" of the immediate external world effects a miniature Copernican Revolution. At a starting point of this development the neonate grasps everything to himself—or, in more precise terms, to his own body—whereas at the termination of this period, i.e., when language and thought begin, he is for all practical purposes but one element or entity among others in a *universe that he has gradually constructed himself*, and which hereafter he will experience as external to himself. (Piaget, quoted in Bodner, 1986, p. 875; emphasis added)

All humans pass through the same stages of cognitive development at around the same age, according to Piaget. Piaget believed that children pass through a largely invariable and universal sequence of four stages:

1. *Sensorimotor* (birth to approximately 2 years of age): a period in which infants begin to construct an understanding of the world through the senses and through movement. Sensory experiences (seeing, hearing) are coordinated with physical, motor actions. Reflexes become intentional actions such as grasping. The infant begins to develop an understanding that objects can exist externally, even if they cannot be seen. The infant also begins to demonstrate goal-directed behavior, such as kicking a ball.
2. *Preoperational* (2 to 7 years): by observing children at play Piaget was able to demonstrate that around the age of 2 years, the child exhibits a qualitatively new stage of development, which he termed preoperational. At the preoperational stage of development the child is able to mentally act on objects and to represent objects using words and drawings, but is not yet able to think through actions. The child also engages in collective monologue with other children, each child is talking but not interacting with other children. Children are considered egocentric at this stage, assuming that others share their point of view.
3. *Concrete operational* (7 to 11 years): by around the age of 7, a child is able to use logic appropriately and to solve actual problems, although not abstract problems. This is the stage of concrete operations, best learned through hands-on learning and discovery while working with tangible objects.
4. *Formal operational* (12+ years): This stage commences at around 12 years of age (puberty) and continues into adulthood. In this stage, individuals move beyond concrete experiences

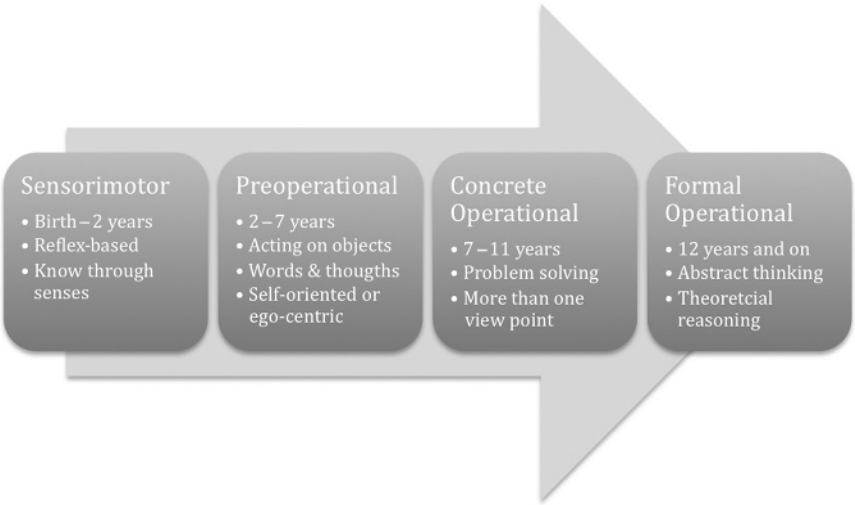


Figure 5.1 Piaget's Stages of Cognitive Development.

> and begin to think abstractly, reason logically and draw conclusions from the information available, as well as apply all these processes to hypothetical situations. During this stage the young adult is able to understand such things as love, entertain possibilities for the future and become more aware of social issues. (Santrock, 2008, pp. 221–223)

These four stages of development are posited by Piaget as the psychological states that children pass through as they grow up. Related to these four stages is the mechanism by which children move from one stage to the next. Piaget's concept of constructivism relates to his studies of how knowledge is internalized and how people learn. Humans, according to Piaget, internalize knowledge through experience and make sense of these experiences through adaptation involving processes of: *assimilation*, *accommodation* and *equilibration/disequilibration*. It is through these three processes that we learn, outgrow some ideas and adopt new ones. These concepts reflect both Piaget's model of intellectual development and his constructivist theory of knowledge.

Assimilation occurs when a child or person comes across a new object or event and makes sense of it by assimilating the information about the object (for example, learning a new word). Assimilation involves applying a pre-existing mental structure to interpreting sensory data. This is true for the reflex action of a newborn to suck, and is a constant process throughout life. Disequilibration occurs when an action cannot be assimilated into pre-existing structures or when we cannot achieve the goals we seek (sucking a thumb not a nipple does not lead to food or when what we learned does not accomplish our goal). Accommodation occurs when the person realizes that the activity does not achieve the expected result, and that existing schemes or operations must be modified. We must accommodate new ways of making sense of an object or event. Constructivism is meaning-making through activity, according to one's age and stage of development.

An instructor, for example, seeks to stimulate conceptual change by challenging a student's existing concepts in order to create cognitive disequilibration. The student will try to restore equilibrium or resolve the problem. Through a process of disequilibration and requilibration, the student constructs new cognitive structures.

Piaget was concerned with epistemology and the question of how knowledge is acquired. Rather than view knowledge as matching reality, as in the objectivist epistemology, Piaget held

that knowledge is constructed as the learner seeks to find an equilibrium between the biological processes of assimilation and accommodation, through the cognitive functions of organization and adaptation (internal self-regulating mechanisms).

The basic tenet of Piaget's constructivism is that knowledge is constructed in the mind of the learner. Whereas the traditional (objectivist) view of knowledge is that of a *match with reality*, Piaget's constructivist view is that knowledge is a *fit with reality*. The learner is not an empty vessel to be filled with the knowledge of the teacher, but is an active organism creating meaning through contact and interaction with the external world.

Piaget distinguished among three types of knowledge that children acquire: physical, logico-mathematical and social knowledge (Piaget, 1969).

1. Physical knowledge is associated with empirical knowledge, which is knowledge about physical objects available from the perceptual properties of objects: size, color, thickness, texture, taste and sound. For example, a ball bounces whereas glass breaks when dropped on the floor.
2. Logico-mathematical knowledge is related to abstract knowledge about objects, such as number, volume, mass, weight, time, speed and size. Comparing the different rate of bouncing between a basketball and a baseball dropped on the floor is an example of logico-mathematical knowledge.
3. Social knowledge is culture-specific and can only be learned in one's own culture, through actions on or interactions with people. Examples include cultural symbol systems, music, history and language. Playing in a basketball competition on a day called Saturday exemplifies social conventions about dates and sports.

Understanding the types of knowledge that Piaget identified is important but not easy. As Ernest von Glasersfeld, also a Piagetian scholar, writes:

> Any serious attempt to come to terms with Piaget's epistemological beliefs runs into three formidable obstacles. First, the simple fact that during his productive lifetime—well over 60 years—he wrote more than any one person could keep up with; and his ideas, of course, developed, interacted, and changed in more and less subtle ways. Second, as Piaget himself is reputed to have said, he spoke one language to biologists, another to psychologists, and yet another to philosophers; and one could add that, apart from these, he invented a private one to speak about mathematics. Third, although he never ceased to praise the virtue of "decentration"—the ability to shift perspective—as a writer, it seems, he did not often try to put himself into his readers' shoes. His passionate effort to express his thoughts in the greatest possible detail impedes understanding as often as it helps it. Even the best intentioned reader is sometimes reduced to a state of exhausted despondence. Yet, I have not the slightest doubt that it is worth struggling to overcome these obstacles, because it can lead to an interpretation that provides a view of human knowledge and the process of knowing which, it seems to me, is more coherent and more plausible than any other. (Von Glasersfeld, 1982, p. 612)

Von Glasersfeld explains what he considers to be the key point of cognitive constructivism: "For a constructivist," he writes,

> that is how it has to be. From that perspective there is no way of transferring knowledge—every knower has to build it up for himself. The cognitive organism is first and foremost an

> organizer who interprets experience and, by interpretation, shapes it into a structured world. That goes for experiencing what we call sensory objects and events, experiencing language and others; and it goes no less for experiencing oneself. (Von Glasersfeld, 1982, p. 612)

As with any major school of thought there are many critiques of Piaget. Von Glasersfeld referred to the obstacles of understanding Piaget, given his vast number of publications. In addition, as von Glasersfeld also noted, Piaget spoke many disciplinary languages and studied and wrote about many fields, and this in itself causes confusion and obstacles for readers.

Seymour Papert, who introduced constructivist computing to school children, notes that Piaget's real interests and contributions were epistemology, an area overlooked by educators. Papert wrote about Piaget in *Time* magazine's 1999 special issue on the "Century's Greatest Minds":

> Although every teacher in training memorizes Piaget's four stages of childhood development, the better part of Piaget is less well known, perhaps because schools of education regard it as "too deep" for teachers. Piaget never thought of himself as a child psychologist. His real interest was epistemology—the theory of knowledge…
>
> The core of Piaget is his belief that looking carefully at how knowledge develops in children will elucidate the nature of knowledge in general. Whether this has in fact led to deeper understanding remains, like everything about Piaget, controversial. (p. 105)

However, more fundamental theoretical arguments have also been raised. One such critique comes from Howard Gardner, a psychologist at Harvard University and author of many books about multiple intelligences. In response to the question put to many well-known scholars and public figures in 2008: "What did you change your mind about?," Gardner wrote that he changed his mind about Piaget's theory of learning. The focus of Gardner's thought piece "Wrestling with Jean Piaget, My Paragon," is presented below.

> I thought that Piaget had identified the most important question in cognitive psychology—how does the mind develop; developed brilliant methods of observation and experimentation; and put forth a convincing picture of development—a set of general cognitive operations that unfold in the course of essentially lockstep, universally occurring stages. I wrote my first books about Piaget; saw myself as carrying on the Piagetian tradition in my own studies of artistic and symbolic development (two areas that he had not focused on); and even defended Piaget vigorously in print against those who would critique his approach and claims.
>
> Yet, now forty years later, I have come to realize that the bulk of my scholarly career has been a critique of the principal claims that Piaget put forth. As to the specifics of how I changed my mind:
>
> Piaget believed in general stages of development that cut across contents (space, time, number); I now believe that each area of content has its own rules and operations and I am dubious about the existence of general stages and structures.
>
> Piaget believed that intelligence was a single general capacity that developed pretty much in the same way across individuals: I now believe that humans possess a number of relatively independent intelligences and these can function and interact in idiosyncratic ways…
>
> …Finally, Piaget saw language and other symbols systems (graphic, musical, bodily etc) as manifestations, almost epiphenomena, of a single cognitive motor; I see each of these systems as having its own origins and being heavily colored by the particular uses to which a system is put in one's own culture and one's own time.

> Why I changed my mind is an issue principally of biography: some of the change has to do with my own choices (I worked for 20 years with brain damaged patients); and some with the Zeitgeist (I was strongly influenced by the ideas of Noam Chomsky and Jerry Fodor, on the one hand, and by empirical discoveries in psychology and biology on the other). (Gardner, 2008)

Vygotsky

Lev Semyonovich Vygotsky (1896–1934), a Russian psychologist, is the scholar today most prominently associated with constructivism. He proposed a theory of cognitive development that emphasized the underlying process rather than the ultimate stage of human development and he focused on the social rather than individual context of human cognitive development. Vygotsky's view of constructivism was a reaction against that of Piaget. Vygotsky focused on the relationship between the cognitive process and a subject's social activities. Whereas Piaget focused on what is biological human development, i.e., individual development, Vygotsky emphasized the social context of human development and learning. Piaget placed the developmental stage before learning, whereas Vygotsky placed learning before development. Piaget emphasized biological development (the theory of stages); learning, for Vygotsky, preceded and led to development.

Vygotsky's theories are most famously presented in his book *Thought and Language*, written shortly before his early death. The title of the book illuminates Vygotsky's position that thought and language are integral to one another. Vygotsky argued that humans, even as infants, engage in internal dialogue, and it is the internalization of this dialogue that leads to speech and thought. All humans are taught language by adults and others, who speak to the child, point at and name things and introduce language to make meaning of the child's experiences. Jerome Bruner, the American psychologist who brought Vygotsky to the notice of American educators, notes that Vygotsky used the epigraph "*Natura parendo vincitur*."

> For it is the internalization of overt action that makes thought, and particularly the internationalization of external dialogue that brings the powerful tool of language to bear on the stream of thought. Man, if you will, is shaped by the tools and instruments that he comes to use, and neither the mind nor the hand alone can amount to much.… And if neither hand nor intellect alone prevails, the tools and aids that do are the developing streams of internalized language and conceptual thought that sometimes run parallel and sometimes merge, each affecting the other. (Bruner, 1962, vi–vii)

Vygotsky's approach to human development was fundamentally different from that of other developmental psychologists. Rather than focusing on a particular period of development, most commonly how a child becomes an adult, Vygotsky posed research questions with a broader perspective: what is the process of intellectual development from birth to death.

Vygotsky studied the processes of how a child developed, rather than how well the child performed: what did the child do under various task conditions and how did the child respond to the task. Vygotsky also considered the importance of tool invention and use as a prerequisite but not sufficient condition for the evolution of cognitive functioning. What was of key importance, for Vygotsky, was the role of social and cultural factors: biological development does not occur in isolation. Thus the basic human condition is based on social use of tools. The development of culture was the internalization of the tools of the culture. Vygotsky offered a socio-historical perspective: tools emerge and change, as do cultures. Tools are part of our cultural and cognitive development.

Social interactions are an essential part of human cognitive development, Vygotsky argued. Thus while other animals may also use tools, humans went beyond that to develop social speech.

Whereas other theories of human development focused on the individual, Vygotsky focused on social activity. Rather than viewing development as the progress from the individual into social relations, Vygotsky posited the opposite: he viewed socialization as leading to higher (individual) cognitive functions. Moreover, the process of conversion from social relations to psychological function is mediated by some kind of link or tools. A tool is something that extends our abilities in the service of something else, while a sign signifies something else.

Human speech is a key example: Vygotsky emphasized both egocentric speech and social speech. He wrote that whereas Piaget viewed egocentric speech as reflecting egocentric thought and reasoning in a preoperational child, a pattern which then disappears as the logical operations of the next stage are acquired, Vygotsky himself believed that egocentric speech evolves into inner speech. It does not disappear, but "denotes a developing abstraction from sound, the child's new faculty to 'think words' instead of pronouncing them" (1962, p. 135). All known facts of egocentric speech, writes Vygotsky, point to one thing: "It develops in the direction of inner speech … egocentric speech is not yet separated from social speech" (1962, pp. 135–136). Based on his experiments, Vygotsky concluded that as children become more aware of themselves as individuals within a social world, their egocentric speech becomes subvocal and inner-directed. Egocentric speech leads to inner-directed thought; thought then leads to social speech.

Vygotsky's theory of intellectual development is also a theory of learning; he studied the behavior of young children where there is a "prelinguistic phase in the use of thought and a preintellectual phase in the use of speech" (Bruner, 1962, vii).

The title of Vygotsky's 1962 book was translated from Russian as "thought and language." It could also be translated as "thinking and speaking." Thought and speech are highly interrelated in Vygotsky's theory.

Vygotsky's theory of learning emphasizes the role of the social and cultural influences on our thoughts and language. Vygotsky created the concept of ZPD, the "zone of proximal development" (proximal is a term meaning nearest). According to ZPD, learning takes place when learners solve problems beyond their actual developmental level—but within their level of potential development—under adult guidance or in collaboration with more capable peers. What this means is guided or supported learning. This does not suggest that the instructor guides the learner to the instructor's

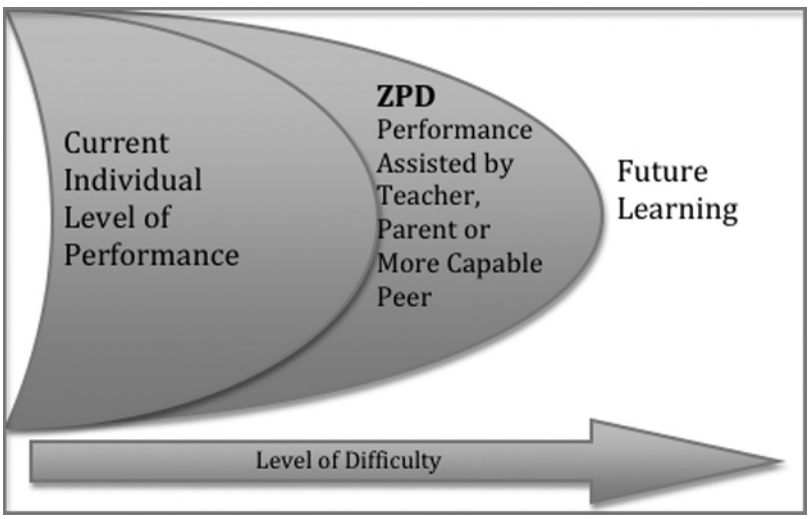


Figure 5.2 Zone of Proximal Development.

intended goal through successive approximations (as in Skinner's behaviorism), but on the contrary, that the more advanced peer or teacher (or parent) supports the learner by providing the tools (language, concepts) needed to advance and eventually independently achieve the learner's intended goal.

Although Vygotsky never used the term scaffolding as a metaphor, it has become closely associated with ZPD, in which the peer or adult supports the learner in constructing knowledge. Scaffolds in learning can be compared with the use of scaffolds in the construction of buildings.

> The scaffold, as it is known in building construction, has five characteristics: It provides a support; it functions as a tool; it extends the range of the worker; it allows the worker to accomplish a task not otherwise possible; and it is used selectively to aid the worker where needed … a scaffold would not be used, for example, when a carpenter is working five feet from the ground. (Greenfield, 1984, p. 118)

In the classroom, a scaffold is a set of activities designed by the teacher to assist the learner move through increasingly difficult tasks to master a new skill. The teacher designs the classroom activities based on the student's prior knowledge, that is, for example, what they learned previously in the classroom or perhaps through other life experience. Classroom activities are designed to help move students from point A to point B, to progress from what they know to what they need to know to complete the course or the class unit—to bring them through the zone of proximal development to achieve their potential.

Constructivist Learning Pedagogy

How we perceive knowledge and the process of "coming to know" shapes our educational practice. If we believe that learners passively receive information, then priority in instruction will be on transmission of knowledge to the learner. If, on the other hand, we believe that learners actively construct knowledge in their attempts to make sense of their world, then instruction is likely to emphasize the development of meaning and understanding.

Constructivist pedagogies focus on the learner or group of learners, while pedagogies associated with behaviorist and cognitivist theories focus on the instructional designer or instructor rather than the learner in the organization of learning. Constructivist learning theory focuses on the role of the learner in making meaning and constructing understanding. Both Piaget and Vygotsky emphasized the active role of the learner, but whereas Piaget emphasized stages of behavior and the child's accomplishment according to preceding developmental stages, Vygotsky emphasized the importance of social interaction. Children, according to Vygotsky, build new concepts by interacting with others and receiving feedback on their hypotheses or the task that they are seeking to accomplish. This is the zone of proximal development, in which a child discusses a problem, a task or a concept with an adult or competent peer who can assist the child by providing the language needed to solve the problem or accomplish the task. The child internalizes the language until she or he is able to complete the task independently.

The constructivist view of learning has generated a number of teaching approaches, based on the following four key principles or values:

1. Active learning
2. Learning-by-doing
3. Scaffolded learning, and
4. Collaborative learning.

Active Learning

In the most general sense, active learning means encouraging students to participate and act, such as conduct a real experiment, rather than passive learning (listening to a lecture, reading a book). Active learning is typically student-centered, and the role of the student is to engage in an activity, such as constructing and testing a theory, hypothesis or strategy. Students then reflect on and discuss what they are doing and how their understanding is changing. The teacher must understand the students' pre-existing conceptions and guide the activity to address, build on and refine pre-existing conceptions.

Contrary to criticisms by some educators, constructivism does not dismiss the active role of the teacher or the value of a parent or a knowledge expert. Rather than transmit information or knowledge to the student, however, the constructivist teacher encourages and assists students in constructing their knowledge about a subject rather than reproducing a series of facts about it. The constructivist teacher introduces techniques such as problem-solving and inquiry-based learning activities whereby students formulate and test their ideas, and draw conclusions and inferences. They may do this individually or pool and convey their knowledge in a collaborative learning environment. The learner is viewed as an active participant in the learning process. Guided by the teacher, students actively construct their knowledge rather than mechanically ingest knowledge from the teacher or the textbook. The teacher thus plays an active and essential role, assisting in identifying a knowledge problem, providing guidance in how to understand it and suggesting resources. The problem (or question) should be interesting, relevant, appropriate and engaging to the learner, so that the student feels that it is her or his knowledge problem. In addition, the problem should be what educators refer to as "ill-defined" or "ill-structured," meaning that it is not just an easy problem, but one that is like problems in the real-world. It should be complex. And authentic, in that it reflects what practitioners do. Authentic activities focus on active learning in real-world contexts, and typically involve production, rather than activities that are abstract or remote from practice.

Constructivism seeks to tap into and trigger the student's innate curiosity about the world and how things work. Students are not expected to reinvent the wheel but to attempt to understand how it turns, how it functions. They are engaged by applying their existing knowledge and real-world experience to the problem, learning to hypothesize, test their theories and ultimately draw conclusions from their findings.

Pedagogies designed in the tradition of active and authentic learning problems may involve individual or collaborative approaches. Bodner, a professor of chemistry, writes about the role of the constructivist teacher in shifting from someone who teaches to someone who *facilitates* learning, teaching by *negotiation* rather than imposition (1986). Bodner notes that social knowledge such as the days of the week or symbols for chemical elements can be taught by rote or direct instruction. And probably should be. "But physical and logico-mathematical knowledge cannot be transferred intact from the mind of the teacher to the mind of the learner" (1986, p. 876). This kind of knowledge benefits from active constructivist learning. Bodner describes a constructivist dialogue between a professor and his students:

> This dialog shows many of the signs of a constructivist teacher who questions students' answers whether they are right or wrong, insists that students explain their answers, focuses the students' attention on the language they are using, does not allow the students to use words or equations without explaining them, and encourages the student to reflect on his or her knowledge, which is an essential part of the learning process. (1986, p. 876)

Learning-by-doing

In *Time* magazine's 1999 special issue on "The Century's Greatest Minds," Seymour Papert cites Albert Einstein as using the words "so simple only a genius could have thought about it" to describe the theory advanced by Piaget that children don't think like adults (p. 105). Papert writes that Piaget

> is revered by generations of teachers inspired by the belief that children are not empty vessels to be filled with knowledge (as traditional pedagogical theory has it), but active builders of knowledge—little scientists who are constantly creating and testing their own theories of the world.

Papert notes that

> Piaget was not an educator and never enunciated rules about how to intervene … But his work strongly suggests that the automatic reaction of putting the child right may well be abusive. Practicing the art of making theories may be more valuable for children. (1999, p. 105)

Papert emphasized "doing something" and "getting something done."

Seymour Papert was a co-founder with Marvin Minsky of the Artificial Intelligence Lab at MIT and a founding faculty member of the MIT Media Lab. Papert collaborated with Piaget at the University of Geneva in the late 1950s and early 1960s. He created the Logo computer programming language used as an educational tool for children. In 1981, he founded Logo Computer Systems Inc. (LCSI) as a publisher of constructivist educational software for K-12 schools around the world. The LCSI website states that: "The constructivist philosophy believes that students excel by building and constructing for themselves the specific knowledge that they need rather than having a teacher dictate numerous facts. Teachers play a role as knowledge facilitators" (Logo Computer Systems Inc., 2002).

Papert is well-known for developing the Logo programming language and applying it in education based on constructivist pedagogy. However, Papert writes, there is more to it than that: what is important is not the programming language but a certain spirit, a "Logo spirit." This spirit or philosophy is based on "doing something," "getting something done." Papert adapted the term "constructivist" to "constructionist," to signify a philosophy of life, a philosophy of learning by doing and especially learning by making.

> The frame of mind behind the Logo culture's attitude to "getting it to happen" is much more than an "educational" or "pedagogic" principle. It is better described as reflecting a "philosophy of life" than a "philosophy of education." But insofar as it can be seen as an aspect of education, it is about something far more specific than constructivism in the usual sense of the word. The principle of getting things done, of making things—and of making them work—is important enough, and different enough from any prevalent ideas about education, that it really needs another name. To cover it and a number of related principles (some of which will be mentioned below) I have adapted the word constructionism to refer to everything that has to do with making things and especially to do with learning by making, an idea that includes but goes far beyond the idea of learning by doing. (Papert, 1999)

Papert writes that education has two wings: one is informational, while the other is constructional. Public perception of technology in general, and educational technology in particular, is a distortion, a one-sidedness that emphasizes the informational and ignores the constructional. It

is a one-sidedness that characterizes as well public views of education, which emphasizes the informational over its constructional role.

> There's education as putting out information; teacher lecturing, reading the book. There's learning by doing, which is the constructional side versus the informational side. And, unfortunately, in our schools the informational side is the one that gets the emphasis, and so there's this line-up between one-sided emphasis in the thinking about school, and the one-sided emphasis in thinking about technology. Both of them emphasizing the informational side, and they reinforce one another. So in many ways, through this, the wrong image we have of what digital technology is about reinforces instead of undermining some of the weaknesses and narrowness of traditional education. (Papert, quoted in Schwartz, 1999)

Papert's constructionism describes an educational philosophy that teaches children to *do* something rather than teaching them *about* something. Some of his early work involved teaching children to be mathematicians rather than teaching them about mathematics in the traditional way.

This led to the Logo language, which is a form of LISP programming language. The Logo language was developed in conjunction with a device called a turtle, which was a small robot holding a pen which could be programmed to draw geometric shapes.

Other constructivist pedagogical approaches include the following:

- *Problem-based learning* (PBL) is the use of a convincing scenario based on a realistic problem presented to a student. Various aspects of the problem may be presented from different perspectives.
- *Distributed problem-based learning* brings together a group of learners working together to solve a problem.
- *Case-based learning* engages students in discussion of specific situations, typically real-world examples. This method is learner-centered, and involves group engagement in building of knowledge and analysis of the case. Much of case-based learning involves learners striving to resolve questions that have no single correct answer; this approach is widely used in such disciplines as medicine, business and education.
- *Inquiry-based learning* is a form of self-directed learning. Students take more responsibility for: determining what they need to know; identifying the appropriate resources; using the resources in their learning; assessing and reporting their learning.
- *Role-play simulation* and *game-based learning*: these are learning processes in which participants act out the roles of specific individuals or organizations in order to develop particular skills and or to assume different perspectives in order to gain a deeper appreciation of the problem being addressed. A simulation or a game involves an artificial environment or plausible scenario that supports the roles, processes and structures of active and authentic learning.

Scaffolded Learning

Vygotsky created the concept of the zone of proximal development (ZPD), which, as noted earlier in this chapter, has also come to be known as scaffolding. With ZPD or scaffolding a more knowledgeable peer or adult supports the learner in constructing knowledge, until the learner no longer needs this support. Scaffolding refers to specialized teaching strategies or tools designed to support learning when students are first introduced to a new subject. Scaffolding gives students a context, motivation and foundation from which to understand the new information. In order for learning to progress, scaffolds should be gradually removed as the learner progresses, so that students will eventually be able to demonstrate comprehension independently. The premise is

that scaffolding is not instruction but a form of collaboration between the teacher and the learner as part of the process of learning, something that the learner could not previously conduct on his or her own but now becomes able to achieve independently. As noted earlier, the term scaffolding derives from the tools that support the construction of buildings. It also refers to the activities of a teacher or mentor or parent to support the child in progressing from his or her actual level of development to achieving the potential level of development.

Collaboration

A key principle of social constructivism is the pedagogical emphasis on the role of "collaboration," particularly among the learners but it can also include collaboration between children and adults, such as teachers, parents or practitioners. Unlike "cooperative learning" in which each group member contributes an independent piece to the whole as a division of labor, in collaborative learning the members participate and interact throughout the process to co-produce a finished artifact or product. However, collaboration does not guarantee the use of constructivist approaches.

> The use of groups may simply be used as an alternative instructional strategy, with little change in the learning goals from traditional didactic instruction … From this perspective, groups are used for reasons that include providing variation in the classroom activity, teaching students how to cooperate and work together, sharing work loads and hence permitting larger projects, and to promote peer tutoring. (Duffy & Cunningham, 1996, pp. 186–187)

Constructivist collaboration, on the other hand, argue Duffy and Cunningham, emphasizes the sharing of alternative viewpoints and challenging or developing each alternative point of view. "Hence, our reason for using groups is to promote the dialogical interchange and reflexivity" (1996, p. 187).

Typically, collaboration refers to a small group (of perhaps three to five students) for a team project or up to 20 students in a group discussion, debate or seminar. Students work together to discuss the topic or to conduct the project.

Collaborative approaches such as scaffolding or cognitive apprenticeship are most often based on interaction between the learner and the teacher. As noted above in the discussion of scaffolding, the support of the teacher is slowly taken away as the learner gains proficiency and learns the topic and becomes able to independently understand and use the concept or tool. This is also the case with ZPD, in which the learner is able to achieve his or her potential through the support of a more knowledgeable other or a teacher.

Lave and Wenger (1991) point to the importance of society's practical knowledge and the learning that goes on among practitioners in communities of practice. Other social constructivist pedagogical approaches include peer collaboration, learning networks or communities: methods that involve group interaction and learning with others.

Constructivist pedagogies have developed outside the learning theories developed by Piaget or Vygotsky. Neither Piaget nor Vygotsky were linked to education during their lifetimes. Piaget was devoted to a tremendous range of interests, but these did not include educational practice. Vygotsky died at a very early age. Educators have nonetheless actively engaged with the notions of constructivist learning, albeit with little theoretical guidance. Concepts of social democracy stemming from the 1970s had strongly influenced education. Hence there has been a strong focus on principles such as active learning, learning by doing and collaboration, but without theoretical clarity on how these techniques contribute to learning and hence how to implement them. The role of the teacher has been unsettled. As noted earlier in this chapter, Papert wrote that: "Piaget was not an educator and never enunciated rules about how to intervene … But his work strongly

suggests that the automatic reaction of putting the child right may well be abusive" (1999, p. 105). Hence, the teacher should not correct the student. Moreover, the teacher should be a participant in the classroom, as the LCSI notes: "We believe that there is such a thing as becoming a good learner and therefore that teachers should do a lot of learning in the presence of the children and in collaboration with them." Popular slogans have emphasized that the role of the constructivist teacher is as "guide on the side" not "sage on the stage." The role of the teacher has been marked by the reactions against instruction, yet without clear alternatives.

Constructivist Learning Technology

The technologies specifically associated with constructivist learning were often referred to as learning environments or microworlds. The term learning environment was primarily associated with computer-based software that is open-ended to enable and require user input, action and agency. It was primarily related to computer-based software, rather than online or web-based environments.

David Jonassen (1994, p. 35) summarized several characteristics as distinguishing constructivist learning environments, such as:

1. provide multiple representations of reality, to avoid oversimplification;
2. "represent the natural complexity of the real world";
3. emphasize knowledge construction instead of knowledge reproduction;
4. emphasize authentic tasks in a meaningful context rather than abstract instruction out of context;
5. provide learning environments such as real-world settings or case-based learning instead of predetermined sequences of instruction;
6. foster thoughtful reflection on experience;
7. "enable context- and content-dependent knowledge construction";
8. support "collaborative construction of knowledge through social negotiation," not competition among learners for recognition.

Jonassen's list has been accepted by both social and cognitivist constructivists, albeit with some differences in emphasis.

Computers are viewed as the optimal medium for applying constructivist principles to educational practice, because computer software can support various strategies and approaches more easily and effectively than other media. Computer software can also link to resources necessary in simulations and microworlds. Computer-based constructivist learning environments such as construction kits, microworlds, scaffolded intentional learning environments, learning networks (telecollaboration) and computer-supported collaborative learning environments were developed in the 1980s and 1990s, and are discussed below.

Construction Kits and Microworlds

In the late 1980s and 1990s educational computer software development sought to support the variety of ways learners construct their own understanding—both as independent work and in collaboration with other learners. Microworlds were designed to provide students with opportunities to connect prior learning with current experience, and they were often created by learners using computer tools as construction kits.

Papert was an early contributor to the computing and the educational world. In fact, he writes that in the 1960s people laughed at him when he talked about children using computers as instruments for learning and for enhancing creativity: the idea of an inexpensive personal computer seemed like science fiction at the time (www.papert.org). But, he notes, it was in his MIT laboratory

that children first had the chance to use the computer to write and to make graphics. The Logo programming language was created there, as were the first children's toys with built-in computation. Logo could be used by students of various ages and computer experience to construct and engage in microworlds.

Logo enabled young learners to experiment in a geometry microworld, creating or constructing objects such as houses, buildings and cities. Logo also enabled students to create objects with motors controlled by the computer, similar to Papert's original turtle robot. Today Logo is linked with the Lego Company, and involves robotics for school children.

Papert viewed programming as key to the constructivist culture. He acknowledges that Logo may not be the solution, but argues that it expresses the liberation of learning from pre-digital learning technologies.

> The Logo programming language is far from all there is to it and in principle we could imagine using a different language, but programming itself is a key element of this culture…
>
> But one can be sure that an alternative culture of educational programming will not emerge soon, or ever … This claim is not based on an arrogant belief that we the inventors of the Logo philosophy are smarter than everyone else. It is based on the belief that the Logo philosophy was not invented at all, but is the expression of the liberation of learning from the artificial constraints of pre-digital knowledge technologies. (Papert, 2002, p. xvi)

Another early contribution to constructivist learning technologies was Apple Computer's HyperCard software. HyperCard was a multimedia database that enabled users to create linkages among multiple objects on a personal computer. Learners used HyperCard to construct presentations on different subjects, selecting and linking a wide range of resources to organize and display information, reports, projects and presentations. One simple example is a classroom postcard project: each student created a HyperCard postcard comprising a message and a graphic. Postcards were bundled and sent as a file online by a teacher in one school to a project classroom elsewhere—where students would read the postcards and respond. In the late 1980s the ability to link graphics with text was a major technological advance, a limited skill among teachers and students.

Mind tools refers to computer tools intended to serve as extensions of the mind. Examples of mind tools are: databases, spreadsheets, emails or concept maps. Jonassen created a software called Mindtools as "a way of using a computer application program to engage learners in constructive, higher-order, critical thinking about the subjects they are studying" (Jonassen, 1996). The learner enters an intellectual partnership with the computer to access and interpret information and organize personal knowledge in new ways, using a database or spreadsheet tool.

Scaffolded Intentional Learning Environments

Computer-based constructivist learning environments were developed during the 1980s and 1990s, and some of these went online using local area networks, mainframe computers or the Internet. CSILE (computer-supported intentional learning environment) was developed by Carl Bereiter and Marlene Scardamalia in 1983, initially at York University, Toronto, and then at the Ontario Institute for Studies in Education, University of Toronto. Scardamalia, Bereiter, McLean, Swallow and Woodruff (1989) wrote:

> There has been a history of attempts in computer-assisted instruction to give students more autonomy or more control over the course of instruction. Usually these attempts presupposed a well-developed repertoire of learning strategies, skills, and goals, without providing means to foster them. (p. 51)

Scardamalia and Bereiter envisioned an environment in which students could learn and practice these metacognitive skills. Their software, called computer-supported intentional learning environments (CSILE), aimed to foster rather than presuppose a student's metacognitive abilities. CSILE software was designed to scaffold knowledge-building activities, using a communal database constructed by learners and their teachers. Students would enter text and/or graphic notes into the database on any topic created by the teacher. All students in the project read one another's notes and could contribute to or comment on them, using computers linked together on a local area network. Authors would be notified when comments were made. In 1983, CSILE was prototyped in a university course and in 1986 it was used for the first time in an elementary school, as a full version. In 1995, the software was redesigned in accordance with the World Wide Web and renamed Knowledge Forum (discussed in Chapter 6).

Learning Networks or Telecollaboration

Another category of constructivist learning environments in the 1980s and 1990s is referred to as telecollaboration or online learning networks (Harasim et al., 1995). Learning network projects began with the use of email running on mainframe computers. The development of the Internet led to a vast number of class–class or school–school network learning activities. One of the earliest examples of online learning networks or telecollaboration was the work by Margaret Riel who created the pedagogical approach of Learning Circles. Learning Circles were student-centered learning projects that began as cross-classroom projects, in which classrooms in different schools and countries communicated by email; by the 1990s, the AT&T telecommunications corporation and then the National Geographic Society offered learners and teachers the opportunity to work with leading scientists. Students also had access to online curriculum units in the sciences in which they collected data and ran and shared their results with others in the network. Riel continues to design, research and direct Learning Circles, a program that brings student/teacher teams from different counties into project-based learning communities over electronic networks. The Learning Circle network is now part of the International Education and Resource Network (iEARN). Riel also helped design the model for Passport to Knowledge, an National Science Foundation-funded "electronic travel" socio-technical network.

Another telecollaboration model is the JASON project founded in 1989 by Robert D. Ballard following his discovery of the shipwreck of the *RMS Titanic*. Given the large interest in this discovery expressed by children, Ballard and his team dedicated themselves to developing ways to enable teachers and students around the world to participate in global explorations using interactive telecommunications such as email. Since then, JASON has connected more than 10 million students and teachers with real scientific exploration and discovery. Participants engage in community-based partnerships related to scientific exploration and analyses. Teacher professional-development programs are also included. For example, "Operation: Resilient Planet" is an ecology curriculum unit based on National Science Education Standards including Science as Inquiry, Physical Science, Life Science, Earth and Space Science, Science in Personal and Social Perspectives and History and Nature of Science. The complete curriculum includes print, video, online games, online labs and fieldwork-based on an interactive website, the JASON Mission Center, where students from across the globe can put their knowledge to work and take the Argonaut Challenge. The JASON Foundation for Education was founded in 1990 as a nonprofit organization to administer the project. The Foundation became a subsidiary of the National Geographic Society in 2005.

MayaQuest is a similar project that enables students to follow and connect with a team of scientists trekking by bicycle through the jungles to remote archeological sites. Students ask questions of the scientists and of the local peoples, and engage in scientific activities using the Internet.

The online learning environment provides access to social/contextual support. Computers are used to assist active experiences—gathering data and resources, conversing with colleagues, struggling through a challenging puzzle or application—or they assist in reflection. For example, while an online conversation through email is an active event, such discussions usually prompt reflection. Teachers can also employ computers as authoring tools for such pedagogies as students' journals and portfolios, to encourage learner examination of experience.

The use of real-world tools, relevant experiences and meaningful data seeks to inject a sense of purpose to classroom activity. Students learn, among other things, to manipulate and analyze raw data, critically evaluate information and operate hardware and software. This technological literacy imparts a very important set of intellectual and technical skills intended to serve students as well in the working world.

The depth and breadth of online information poses its own challenge. Internet content is less structured and manageable than material outlined by a textbook. Information from the Internet is more dynamic than the printed word. Students need to learn to question and evaluate the information they find. There are many Internet sites that offer raw data—pictures from space, numbers from the census and text from court testimony. These resources need context to provide meaning, and lessons should include components that help students use the information wisely and productively, bearing in mind the need to always ascertain the currency and authenticity of the data.

Online Learning and Course Delivery Platforms

The need for online platforms to support the delivery of online courses or educational activities became recognized and in the 1990s a variety of software began to emerge to address this important issue. These platforms were known under various names such as learning management systems, course management tools, virtual learning environments and computer-supported collaborative learning software. Generally, they were not especially customized to scaffold particular learning strategies, but rather provided generic tools such as discussion-forum software bundled with other tools such as a quiz tool, gradebook or calendar. While the field of online education was first based on the use of computer conferencing (and in some cases, email) in the 1980s, in the late 1990s "learning" platforms consisted of a conferencing or forum system, quiz tool, gradebook and other administrative tools. Together, these generic tools could be accessed by the teacher and the learner to support educational projects or courses. Examples of asynchronous learning platforms in the 1990s and 2000s include Blackboard, WebCT, Desire2Learn and Moodle.

Online learning platforms or environments are constructivist in that they facilitate user-generated content; they can be structured by the user (teacher or learner) to support online discussion, discourse and work projects. The environments most used today are generic asynchronous discussion forums with additional tools. The discussion forum can be structured to support subforums (such as seminars with related role plays or small-group discussions), to open or close forums at specific times or dates, to facilitate specific pedagogical activities (a lecture, a podcast, a question-and-answer forum) and other forms of discourse. However, many educators typically use only one or two online tools and ignore the discussion-forum software. For example, teachers may use only the quiz tool and perhaps the gradebook. Or only post the course material online, for students to download. The examples of online quizzes, gradebooks, podcasts or posting of course materials do not engage the learner in constructivist interactions such as discussions, debates or other knowledge-building interactions. Unfortunately, developers of constructivist learning environments could not ensure that teachers would use constructivist pedagogies when using their technologies. As Driscoll notes, the developer of the constructivist computer conferencing software, Construe, acknowledged that the software

could also be "used to support very traditional instructional strategies" (2005, p. 406). Driscoll disagrees. She writes:

> However, as one who has herself employed Construe in a graduate course, I am convinced that the use of all the software's features as an integrated system guarantees a very powerful learning environment that will yield learning outcomes consistent with constructivism. (2005, p. 406)

Nonetheless, the word "guarantees" is likely over-optimistic. The availability of constructivist features does not compel their effective use or their use at all. The lack of educational frameworks and guidelines has held back progress in this area, because teachers do not understand the underlying pedagogies or theory, may not know how to use the various features or do not choose to use them in their classroom or online courses.

Nonetheless, many tools and platforms developed in the 1990s are maturing in the sense of incorporating scaffolds, new pedagogical supports and other features to more explicitly facilitate knowledge building and collaborative learning. Research, field experience and, in the case of open-source software, new environments are emerging to address improvements in the field of online learning and knowledge building, and are discussed in Chapter 6.

Summary

Chapter 5 focused on constructivist learning theory, constructivist pedagogy and associated technologies. As we have seen, there has been an evolution in the nature and focus of learning theories in the 20th century. Behaviorism emphasized stimulus–response, and the need to tightly control the learning through pedagogies and technologies associated with instructional design. Cognitivist learning theory was a reaction to, but also, in certain ways, an extension of, behaviorism. Cognitivism rejected the black-box metaphor of behaviorism and focused instead on the black box, seeking to understand what happens in the mind between the stimulus and response or inputs and outputs. In cognitivism, the mind is primarily represented by computational metaphors such as a cognitive information processing unit or mind as computer. The mind of a student, for example, acquires information sent by a knowledge transmitter, the teacher. The pedagogies and technologies associated with cognitivism emphasize the nature of cognition in order to be able to transfer or transmit the message accurately.

Constructivism introduced a new perspective to 20th-century learning theory, both in terms of theory and epistemology. It offered a perspective that views knowledge as constructed by the learner, either through physical development and maturation as posited by Piaget, or primarily influenced by the socio-cultural context, as theorized by Vygotsky, whereby the mind generates thought, language and knowledge.

Constructivism resonated with practicing teachers and became a highly popular concept in the field. However, neither Piaget nor Vygotsky had ever written about the implications of their theories for the classroom, and hence the resulting constructivist pedagogies and technologies were primarily attempts by practitioners to implement notions of active learning. Constructivist pedagogies were characterized by such broad principles as active learning, learning-by-doing or learning-by-making, scaffolded learning and collaboration. Constructivism also stimulated the development of a variety of technologies and their application. The use of the computer, and eventually computers linked by local area networks and then the Internet, was a powerful catalyst that contributed significantly to the rise of online learning networks and similar applications.

The advance of online technologies in education has, moreover, matured in terms of the potential for knowledge construction. The wealth of experimentation and experience associated

with constructivism in the 1990s has generated new perspectives and advances sharpened by the current paradigmatic changes associated with the rise of the 21st-century Knowledge Age.

In Chapter 6, we focus in particular on the emergence of the Web and the role of collaborative learning in knowledge construction. A theory of Online Collaborative Learning is proposed and delineated.