Constructivism: A Psychological Theory of Learning

Catherine Twomey Fosnot and Randall Stewart Perry

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Psychology—the way learning is defined, studied, and understood—underlies much of the curricular and instructional decision-making that occurs in education. Constructivism, perhaps the most current psychology of learning, is no exception. Initially based on the work of Jean Piaget and Lev Vygotsky, and then supported and extended by contemporary biologists and cognitive scientists as they studied complexity and emergence, it is having major ramifications on the goals that teachers set for the learners with whom they work, the instructional strategies teachers employ in working toward these goals, and the methods of assessment used by school personnel to document genuine learning. What is this theory of learning and development that is the basis of the current reform movement and how is it different from other models of psychology?

INTRODUCTION: THEORIES OF LEARNING

Behaviorism

Behaviorism is the doctrine that regards psychology as a scientific study of behavior and explains learning as a system of behavioral responses to physical stimuli. Psychologists working within this theory of learning are interested in the effect of reinforcement, practice, and external motivation on a network of associations and learned behaviors. Educators using such a behaviorist framework preplan a curriculum by breaking a content area (usually seen as a finite body of predetermined knowledge) into assumed component parts —“skills”—and then sequencing these parts into a hierarchy ranging from simple to more complex. Assumptions are made that observation, listening to explanations from teachers who communicate clearly, or engaging in experiences, activities, or practice sessions with feedback will result in learning; and that proficient skills will quantify to produce the whole, or more encompassing concept (Bloom, 1956; Gagne, 1965). Further, learners are viewed as passive, in need of external motivation, and affected by reinforcement (Skinner, 1953); thus, educators spend their time developing a sequenced, well-structured curriculum and determining how they will assess, motivate, reinforce, and evaluate the learner. The learner is simply tested to see where he or she falls on the curriculum continuum and then expected to progress in a linear, quantitative fashion as long as clear communication and appropriate motivation, practice, and reinforcement are provided. Progress by learners is assessed by measuring observable outcomes—namely, behaviors on predetermined tasks. The mastery learning model (Bloom, 1976) is a case in point. This model makes the assumption that wholes can be broken into parts, that skills can be broken into subskills, and that these skills can be sequenced in a "learning line." Learners are diagnosed in terms of deficiencies, called "needs," then taught until "mastery"—defined as behavioral competence—is achieved at each of the sequenced levels. Further, it is assumed that if mastery is achieved at each level then the more general concept (defined by the accumulation of the skills) has also been taught. It is important to note the use of the term "skill" here as the outcome of learning and the goal of teaching. The term itself is derived from the notion of behavioral competence. Although few schools today use the mastery learning model rigidly, much of the prevalent traditional educational practice still in place stems from this behaviorist psychology. Behaviorist theory may have implications for changing behavior, but it offers little in the way of explaining cognitive change—a structural change in understanding.

Maturationism

In contrast, maturationism is a theory that describes conceptual knowledge as dependent on the developmental stage of the learner, which in turn is the result of a natural unfolding of innate biological programming. From this perspective learners are viewed as active meaning-makers, interpreting experience with cognitive structures that are the result of maturation; thus, age norms for these cognitive maturations are important as predictors of behavior. Psychologists working within this paradigm focused on delineating stages of growth and behaviors characteristic of each stage. For example, Erikson (1950) studied the development of the concept of identity and proposed eight stages, each having a developmental crisis which he felt needed to be worked through for a healthy self-image to result; and Gesell (1940; Gesell & Ilg, 1946; Gesell et al., 1956), working with his colleagues Ilg and Ames, studied children at different ages and characterized their behaviors into age-dependent stages. The educator's role, from this perspective, is to prepare an enriched, developmentally appropriate environment. Learners are assessed in relation to developmental milestones, such as conservation tasks or Gesellian-based kindergarten screening tasks. Further, the curriculum is analyzed for its cognitive requirements on learners, and then matched to the learner's stage of development. Early attempts to apply Piaget's theory to education were based on this theory. His stage theory was misinterpreted as a maturationist theory, thus learners were assessed with a battery of tasks to ascertain whether they were preoperational, concrete-operational, or formal-operational. These global stages were seen as hierarchical and used as delimiters and/or goals of curriculum, and instructional methods were prescribed in relation to the stages in generalities such as "learners need concrete materials when they are in the concrete-operational stage." Models of teaching commonly known as "developmentally appropriate practice" evolved from this theory, as depicted in the 1988 position statement written by the National Association for the Education of Young Children:

> Between 6 and 9 years of age, children begin to acquire the mental ability to think about and solve problems in their heads because they can then manipulate objects symbolically—no longer always having to touch or move them. This is a major cognitive achievement for children that extends their ability to solve problems. While they can symbolically or mentally manipulate, it will be some time before they can mentally manipulate symbols, for example, to solve mathematical problems such as missing addends or to grasp algebra. For this reason, primary age children still need real things to think about … in addition, appropriate schools recognize that some thinking skills, such as understanding mathematical place value and "borrowing" in subtraction, are beyond the cognitive capacity of children who are developing concrete operational thinking and so do not introduce these skills to most children until they are 8 or 9 years of age. (1988, pp. 65–66)

Constructivism

As pointed out by von Glasersfeld in Chapter 1, constructivism is fundamentally nonpositivist and as such it stands on completely new ground, often in direct opposition to both behaviorism and maturationism. Rather than behaviors or skills as the goal of instruction, *cognitive development* and *deep understanding* are the foci; rather than stages being the result of maturation, they are understood as *constructions of active learner reorganization*. Rather than viewing learning as a linear process, it is understood to be *complex* and fundamentally *nonlinear* in nature. Constructivism, as a psychological theory, stems from the burgeoning field of cognitive science, particularly the later work of Jean Piaget just prior to his death in 1980, the sociohistorical work of Lev Vygotsky and his followers, and the work of Jerome Bruner, Howard Gardner, and Nelson Goodman, among others who have studied the role of representation in learning. It also has roots in biology and evolution—the logical outcome of the work of contemporary scientists such as Ilya Prigogine, Humberto Maturana, Francisco Varela, Ernst Mayr, Murray Gell-Man, Wolfgang Krumbein, Betsy Dyer, Lynn Margulis, Stuart Kauffman, and Per Bak (among others), as attempts were made to unify physics with biology. The remainder of this chapter will present a description of the work of these scientists and then a synthesis will be developed to describe and define constructivism as a psychological theory of evolution and development.

THE BIOLOGICAL LANDSCAPE OF LEARNING: EVOLUTIONARY SYSTEMS

Knowing and cognitive processes are rooted in our biological structure. The mechanisms by which life evolved—from chemical beginnings to cognizing human beings—are central to understanding the psychological basis of learning. We are the product of an evolutionary process and it is the mechanisms inherent in this process that offer the most probable explanations to how we think and learn.

Environmental Equivalence

Life evolved from the chemicals and substrates on early Earth. Complex inorganic- and carbon-based chemicals coevolved with their environment. One cannot separate one from the other any more than we can separate the construction of knowledge from its environment. We introduce the term "environmental equivalence" to emphasize the importance of the idea of equivalence—the active interplay of the surround (environment), to evolution *and* to learning. The environment of an organism is composed of itself (and its neurological events), the population of other organisms, and the physical nature of its surround. Organisms create their environment and are created by their environment. Thus, "The environment itself has about the equivalent power and influence as the biota and both communicate with each other in equilibrated and successful ways to keep the total system going" (Krumbein & Dyer, 1985, p. 150). Neither the organism nor learners are passive objects to their change, a point also made by Piaget when he suggested that both Lamarckian and Darwinian models of evolution were too extreme.

Biological Equilibration

Although Piaget's writings appeared over a 50-year span, it is the work done in the 10 to 15 years prior to his death that serves as a beginning point for the psychological basis of constructivism. During this time period, rather than discussing global stages as descriptive of learning as he had done in his earlier writings, he and his colleagues focused on the mechanism of learning. Rather than labeling the type of logic used by learners, that is, preoperational, concrete, or formal (as they had done in their earlier work), they focused on the *process* that enabled new constructions—new perspectives—to come about. Piaget had proposed equilibration as the mechanism to explain development very early in his career, but it was in the last 15 years of his life that he returned to this study, delineating it further and even eventually reformulating his model. In order to understand fully the mechanism of equilibration, a discussion of Piaget's early work as a biologist studying snails is important. Piaget's fascination centered on the variability of the snail's adaptation. He studied three separate groups of Limnaea stagnalis: those that live in still, tranquil clear waters (habitat A); those that live in mildly disturbed waters agitated by waves (habitat B); and those that live in severely disturbed waters agitated by high winds and waves (habitat C). While the shape of the snail in calm water was elongated, the shapes of the snails in both types of agitated water were the same—globular and curved. See Figure 2.1.

Piaget believed that the globular shape was due to the activity of the snails. The animal in the course of its growth attaches itself to its solid support, which dilates the opening. At the same time and even because of this, it draws on the muscle that attaches it to its shell, and this tends to shorten the spine, that is, the upper part of the spiral shell (Gallagher & Reid, 1982, p. 22). Piaget noticed that the globular snails of habitat B that had globular offspring in habitat B, when removed and placed in an aquarium (habitat A) had offspring that were elongated. This showed that the change in structure was only a phenotypic change, not a permanent genetic change. In contrast the snails of habitat C, although they looked exactly like the snails in habitat B, showed no change even when they were left in an aquarium for 16 years, and their offspring were globular. In other words, the snails in habitat C were distinctly different, having a different genotype. From these observations, as well as from observations of plant growth, Piaget proposed a middle ground position between the commonly held theories of that time—Lamarck's and Darwin's. Lamarck (1809) had proposed that evolution was a result of the organism's adjustment or accommodation to the environment's pressure; for a species to survive in a changing environment it made structural, genetic changes, acquired changes as a result of behaviors that were adaptive in nature. Darwin (1859) took a different view. He proposed that evolution was due to chance mutations, a method for selection generated by the organism, and that the mutations more suited to the environment would be carried on—a survival of the fittest, so to speak. Piaget criticized both Lamarck's and Darwin's theories as being too extreme—the former as mechanistic, the latter as purposeless (Doll, 1993). In contrast, Piaget took the position that the activity of the organism drives the evolution of new structures because the development of new behavior more or less causes an imbalance in the genome, the regulatory system of the genetic structure. This perturbation causes a series of possibilities to result in the genome. And then (in line with Darwin's theory of evolution) the possibilities most suited to the environment survive. Piaget viewed behavior and the organism as a whole system, such that any change in a part of the system would result in other changes as behavior balanced the structure of the organism against the characteristics of the environment. Although Piaget's work in biology did not receive much attention during his lifetime from researchers in the field (the exception being Waddington, 1957), a renewed interest has occurred in the work of contemporary scientists as they explore chaos theory and dissipative structures.

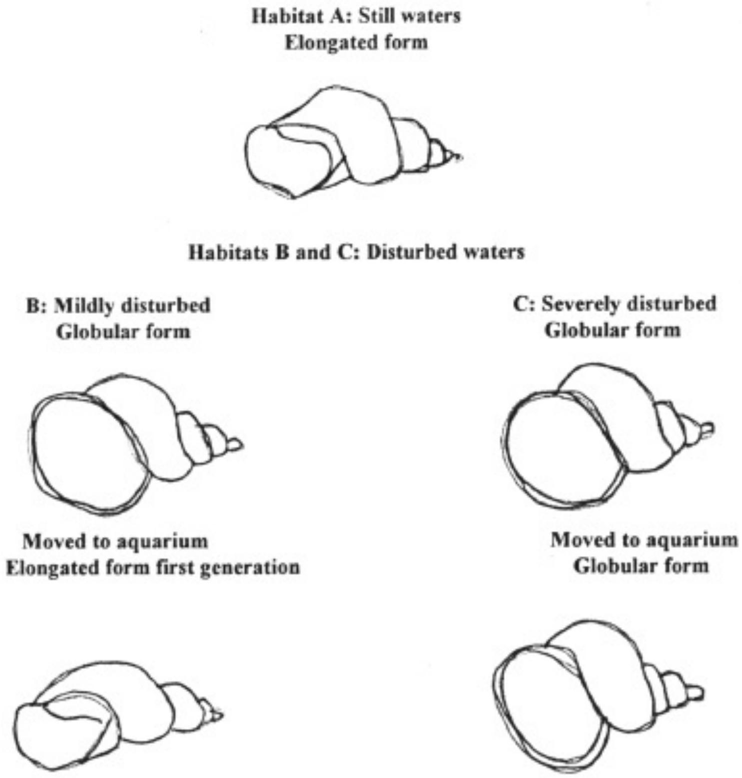

FIGURE 2.1. Pond snail (*Limnaea stagnalis*) as an example of biological equilibration.

Dissipative Structures

For cells to live, evolve, and flourish, there must be an exchange of matter and energy with the environment around them. The flow of matter and energy through complex systems has been described by the Nobel Laureate Ilya Prigogine as a dissipative structure—an open system that maintains itself in a state far from equilibrium. Dissipative structures produce new forms of order—order that arises spontaneously in a complex system when it is far from equilibrium, at "the edge of the chaos." When the flow of energy increases, the increased activity produces instability and a "bifurcation" results. At this bifurcation point, reorganizing occurs—self-organizing that results in the emergence of a new structure for coherence and efficiency. Without dissipative structures, without exchange with the environment, entropy would result. Capra explains the importance of this model:

> This spontaneous emergence of order at critical points of instability is one of the most important concepts of the new understanding of life. It is technically known as self-organization and is often referred to simply as "emergence." It has been recognized as

> the dynamic origin of development, learning, and evolution. In other words, creativity—the generation of new forms—is a key property of all living systems. And since emergence is an integral part of dynamics of open systems, we reach the important conclusion that open systems develop and evolve. Life constantly reaches out into novelty. (Capra, 2002, p. 14)

Transition Zones

Before self-order and complexity can evolve, they are one with their environment. The time between the emergence of the chaotic environment that leads to bifurcations and novel structures and a preceding time of stasis is a transition zone. This explanation was first introduced by Perry and Kolb (2003, 2004) to bridge time between nonliving chemicals and life (as we know it). The transition zone is a gradual time interspersed with flurries of changes that lead to bifurcations. Self-organization, Darwinian evolution (selection and adaptation), and transitions to life proceed slowly over time. Although the time scale may be long, these transitions are not smooth but rather interspersed with cascades of change or "punctuated evolution" (Eldredge & Gould, 1972, as they applied it to developed life). This "first order coupling" with the environment (Maturana & Varela, 1998), allows for the formation of dissipative structures, in effect miniature Gaia. Just as whirlwinds appear from seemingly quiescent cloudless days, activity in transition zones such as prebiotic systems and in single cell organisms leads to development and organized structures. In transition zones over time, a myriad of changes and combinations between early pre-biotic molecules evolved and may or may not have led to life (Perry & Kolb, 2003). Only some of the bifurcations produced favorable changes for selection; others were dead ends. But, as "knowledge" (adaptation) improved, fidelity of replication became more reliable and chemical systems evolved toward cellular life. Evolution to life was gradual but punctuated with chaotic or quantum events. When the chemical stage was set, life emerged from the transition zone and did not form only a proto-cell, but "googles." Materials from the surround entered (Kauffman, 1993; Margulis, 1982) and left evolving cells (Perry & Kolb, 2004) and formed symbiotic relationships in an interactive dance leading to biological life and developed cognitive systems.

Emergence to Complex Systems: Second Order Coupling

Biological forms and functions are not simply determined by a genetic blueprint, but are emergent properties of an entire epigenetic living network. These networks continually create, or re-create, themselves by transforming or replacing their components. Just as single cell organisms exchange matter and energy via dissipative structures, complex organic systems undergo continual structural changes while preserving their weblike patterns of organization (Capra, 2002). This autopoetic dynamic of organic systems has been termed "second order coupling" by Maturana and Varela (1998). An interplay between the surround and the developing system forms whether the system consists of evolving chemicals, biology, or learners and "thus they [organisms] create their environment and in response to their environment they create themselves" (Krumbein & Dyer, 1985, p. 150).

Diversity and Deselection

As order evolves in far from equilibrium nonlinear systems, many paths are deselected and remaining paths are chosen (Prigogine, 1997). Systems before life (as we know it) might be bidirectional, evolving to more or less complexity, but as complexity increases in nonequilibrium systems, new forms of order develop (Gell-Mann, 1994; Prigogine, 1997). Life is the opposite of stasis. Isolation and stasis over time would result in a system running down—entropy, death. Natural selection increases the diversity while at the same time deselecting some of the possibilities. It also thriftily conserves the activity and self-organization accomplished at each stage so that it doesn't have to be done over again (Dennett, 1995). Over eons of time a diversity of species has evolved and less viable organisms have been deselected. Further, structural self-organizing within species also has occurred—that is, *Homo sapiens* have evolved myelination and neuronal networks that allow for language and thought. As we couple with our surround (including others) we evolve ideas and explanatory models that are viable, and deselect those that we deem not viable. Reflection on our activity in the surround, discussed in communities of discourse to generate multiple perspectives (a third-order coupling, Maturana & Varela, 1998) keeps us in a growth-producing, open, evolving state. Recent work in Artificial Intelligence suggests that the generating of diverse possibilities and the subsequent deselection of nonviable activity characterizes learning. Computers programmed to deselect pathways that were deemed not viable after trials, began to self-organize, seemingly learning and constructing new, more efficient pathways, poised in a dynamic state of self-organized criticality (Bak, 1996). This was in stark contrast to computers programmed with positive reinforcement feedback loops, which over time did not self-organize. This position is of course arguable. We continue to make our case by returning to Piaget's work in cognition.

Cognitive Equilibration

Although Piaget's early work was in the field of biology, most of his life was devoted to studying the genesis of cognitive structures. He wrote, "The subject exists because, to put it very briefly, the being of structures consists in their coming to be, that is, their being 'under construction.' … There is no structure apart from construction" (Piaget, 1970, p. 140). In essence, he believed that the human was a developing organism, not only in a physical, biological sense, but also in a cognitive sense. Because he viewed the organism as a whole system, a structure (such that emotional, cognitive, and physical development were indissociable), he proposed and demonstrated through much research that the mechanism promoting change in cognition was the same as that in evolution—namely, equilibration. In fact, he proposed that it was the mechanism at play in any transformational growth process. Equilibration was described by Piaget as a dynamic process of self-regulated behavior balancing two intrinsic polar behaviors, assimilation and accommodation. Assimilation (to make similar) is activity, the organization of experience; it is the individual's self-assertive tendency, a tendency to view, understand, and act on the "surround" with one's own activity or ideas in order to preserve one's autonomy as a part within a whole system. Piaget explains how, at times, this process results in a "reach beyond the grasp" as one evolves, searches for new knowledge, and encounters "new territory." In these new situations the organism's activity attempts to reconstitute previous behaviors to conserve its functioning, but every behavior results in an accommodation that is a result of the effects or pressures of the environment. These progressive experiences sometimes foster contradictions to our present understandings, making them insufficient, thus perturbing and disequilibrating the structure and causing accommodations to reconstitute efficient functioning. Accommodation is comprised of reflective, integrative behavior (reflective abstraction) which serves to change one's own self and explicate the object, in order to function with cognitive equilibrium in relation to it. In *The Development of Thought: Equilibration of Cognitive Structures* (1977), Piaget explained that his "earlier model had proved insufficient and that his central new idea is that knowledge proceeds neither solely from the experience of objects nor from an innate programming performed in the subject but from successive constructions" (preface,). He proposed three models of equilibration. The first is between the assimilation of schemes of action and the accommodation of these to the objects; for example, the infant learning to coordinate gazing, reaching, and sucking in order to grasp a rattle and bring it to the mouth for sucking. The second results from the interactions between two logical ideas that the subject finds contradictory. For example, when faced with the conservation of length task where two roads are depicted using matchsticks (see Figure 2.2), a learner may declare that the bottom row is longer because it goes out farther (a preoperational length idea based on visual clues), and then declare that the top road must be longer because it has more sticks (a number idea based on quantity). The contradiction between these ideas engenders disequilibrium, which is resolved with the construction of the idea of conservation of length (Inhelder, Sinclair, & Bovet, 1974).

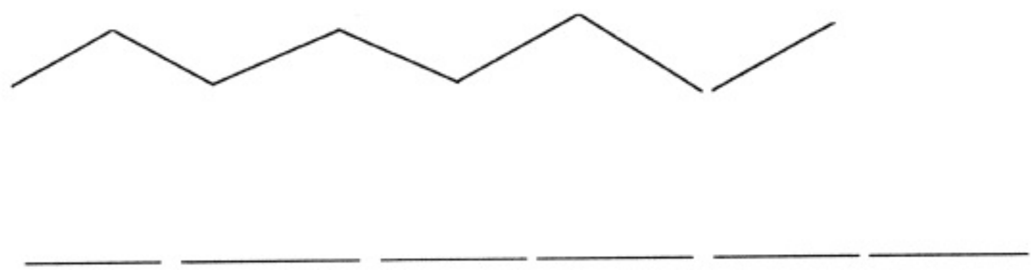

FIGURE 2.2. Conservation of length.

The third form describes the differentiation and the integration of the whole knowledge structure, relations uniting two systems of thought to the totality that includes them. Consider, for example, two referential systems that each describes movement, such as a traveler moving on a train and an observer moving alongside the train. To construct an understanding of the displacement involved, one must coordinate each of the systems into a unified system that includes a differentiation of each of the subsystems. In order to understand the concept of equilibration, one must think of it as a dynamic process in an organism functioning at far from equilibrium states, not as a static equilibrium. Piaget was fascinated by the work of Prigogine on dissipative structures, and the idea of self-organizing as a result of activity and bifurcations was key. Equilibration has often been misinterpreted in the literature. It is not a sequential process of assimilation, then conflict, then accommodation; it is not linear. Nor is assimilation a process of "taking in information" as it has sometimes been described. Equilibration is instead a nonlinear, dynamic "dance' of progressive equilibria, adaptation and organization, growth and change. It results from "coupling" with our surround. As we assert ourselves with our logical constructs and "act on" new experiences and information, we exhibit one pole of behavior

—the pole of activity on the surround; our reflective, integrative, accommodative nature is the other pole—the pole of self-organization. These two poles provide a dynamic interplay, which by its own intrinsic, dissipative nature serves to keep the system in an open, flexible, growth-producing state. Piaget writes:

> Cognitive equilibriums are quite different from mechanical equilibriums which conserve themselves without modifications or, in the case of "displacement," give rise merely to moderations of the disturbance and not to whole compensations. They differ even more from thermodynamic equilibrium (except when it is reversible), which is a state of rest after destruction of structures. Cognitive equilibriums are closer to those stationary but dynamic states, mentioned by Prigogine, with exchanges capable of "building and maintaining a functional and structural order in an open system," and they resemble above all … the biological … dynamic equilibriums. (1977, p. 4)

Contradiction

At successive points in this spiraling equilibration, learners construct contradictions to their actions and ideas. These contradictions may be in the form of actions on objects that are not working—for example, an infant who keeps trying to reach for a rattle, but instead keeps bringing only his fist to his mouth. The action of fist to mouth (a primary-circular reaction) becomes insufficient. On the other hand, the contradictions may be in the form of two theories that both seem plausible, and yet are contradictory, or theories that become insufficient given new evidence. Sequences of such contradictions and the subsequent "reequilibria" can be seen in the history of ideas about aspects of the physical world, such as light. Before Newton's time, the notion that light was in the form of rays made it possible for people to explain shadows and "images" from pinholes, but it did not provide a mechanism to explain refraction as light passes through a transparent medium. This was not a big problem until lenses began to be used in Galileo's day. Within one generation the issue was puzzling enough to cause a search for a notion of the nature of light sufficient to handle this inadequacy. Newton suggested that if we thought of light as actual tiny, material particles, spherical in nature, one could explain refraction in terms of a mechanism. He suggested that if you roll actual particles, such as marbles, across a horizontal surface toward a wide ramp sloping down to another horizontal surface you will find that the marbles will approach the ramp traveling in straight lines. At the ramp they will change direction slightly and then change again at the bottom of the ramp, resulting in a change in direction of travel much the same way as light is observed to change direction at the interface between two transparent media. For a while all was well, and light was conceived of as particles by scientists until we could make light sources bright enough and well collimated enough to see detail in the edges of the shadows of objects. Thomas Young resolved the problem this new phenomenon created by convincingly putting forth a wave model of light, in contrast to a particle model. Much later the attempts to interpret the photoelectric effect with a wave model created new problems until Planck, and later Einstein, proved that light was composed of chunks or packets of energy traveling in a similar fashion to billiard balls. When they hit an object they knocked a particle out of the mass of that object, just as a billiard ball hitting another would send it traveling at the same speed as the original ball. This model explained refraction and the photoelectric effect, whereas the wave interpretation had been insufficient, but now a new paradox remained. How could light be packets of energy and yet be waves at the same time? It is important to note here that the paradoxes in the scientists' interpretations existed between the abstractions—for example, light as waves versus light as particles. The experimental results were contradictory only insofar as they fit or contradicted the given abstraction—the currently deemed viable explanation. The notions of light as rays, or waves, or packets of energy are all constructed abstractions as humans evolve, solve problems, and seek coherency. The data by themselves are not contradictory; they are contradictory only in relation to the meaning that the learner (the scientist, in this case) attributes to them. In each of these cases, it is the contradiction (itself a construction on the part of the learner) that causes the imbalance providing the internal motivation for an accommodation. Piaget proposed that three types of compensations, or accommodations, might occur by learners when dealing with such imbalance: (1) they might ignore the contradictions and perseverate with their initial scheme or idea; (2) they might waver, holding both theories simultaneously, dealing with the contradiction by making each theory hold for separate, specific cases; or (3) they might construct a new, more encompassing notion that explains and resolves the prior contradiction. In either case, what is important to note is that all the compensations are a result of the internal, self-organizing behavior of the learner. And Piaget notes that the contradictions are constructed only secondarily after learners first search for similarities between experiences (called affirmations), and attempt to organize each experience with their present schemes. In a sense, the first two levels are like a "transition zone" (Perry & Kolb, 2003) until the organism reaches the edge of chaos from the diversity of explanations (a bifurcation) and begins to deselect and reorganize, thereby evolving a new structure.

Possibilities, Correspondences, and Transformations

So if contradictions are so difficult to construct, and the tendency of all organisms is to preserve themselves, how and why does equilibration ever occur? In two volumes written just before he died (but appearing in English posthumously), Piaget (1987a, 1987b) attempted to address this question. And it is here that one becomes keenly aware of the connection of his cognitive psychology to work in biology. Just as the genome generates new possibilities when disturbed, cognitive structures generate new possibilities when disturbed—possibilities of new actions, or explanations of surprising results. These possibilities are explored and correspondences and/or patterns are constructed because of the human's self-organizing tendency. Subsequent reflection on these correspondences brings about a structural change—an accommodation that transforms the original cognitive structure and one that explains why the pattern occurs, thus enabling generalization beyond the specific experience. Piaget terms this process "reflective abstraction." Possibilities generated by subjects (4 to 8 years of age) as they sought to understand how to balance a series of blocks on a fulcrum are evidence of this process (Fosnot, Forman, Edwards, & Goldhaber, 1988). At first young children tended to plunk blocks randomly on the fulcrum and to push harder or hold them in place if they didn't balance, almost as if they believed that balancing blocks on a fulcrum had to do with stickiness, or the force of their actions. But soon, as they explored this problem further, they began to investigate moving the blocks back and forth across the fulcrum. These procedures resulted at times in balance (with symmetrical blocks), but did not work for asymmetrical blocks; yet children persisted with these actions for some time, even correcting in the wrong direction, seemingly constructing a theory that involved finding the midpoint of their back-and-forth actions! Eventually they began to explore other actions, sometimes correcting in the right direction to restore balance. This successful action generated contradictory data—a negation to their earlier theories. Eventually this contradiction was resolved with the construction of a new theory: find the midpoint of the block, not the midpoint of the back-and-forth actions! This theory eventually met with contradictory data too, though, as learners went on to explore asymmetrically weighted blocks (blocks with more mass on one side, e.g., a ramp-shaped block with lead in the tip). And at first these were even deemed emphatically by children as "impossible" blocks to balance—given their theories! Throughout the sessions exploring the blocks, learners continued to generate possibilities and develop progressively new models to explain balance. Each new perspective resulted in a temporary structural shift in thinking—an example of spiraling equilibration.

Structures

Structures are human constructions—cognitive mental systems with transformational laws that apply to the system as a whole and not only to its elements. Our number system is a good example. When we add two whole numbers together we stay within the system of whole numbers; and the numbers themselves have no meaning except in relation to each other (e.g., 5 has no meaning except as 1 more than 4 or 1 less than 6, etc.). As we watch children exploring quantity, such as various arrangements of 12 apples, for example (1 and 11, 2 and 10, 3 and 9, etc.), we can observe the construction of ideas that describe the transformations of the parts within the system, such as: (1) compensation, 1 and 11 become 2 and 10 because what you gain with one you lose with the other; (2) commutativity, 2 + 10 = 10 + 2; and (3) reversibility, if 10 + 2 = 12, then 12 - 2 must be equal to 10. Structures are characterized by three properties: wholeness, transformation, and self-regulation. Wholeness refers to the fact that the system is a whole that may in fact be larger than the sum of its parts. The parts, interacting and related, are indissociable from each other and the whole and thus have no meaning by themselves. Their meaning is derived only in terms of the whole, and in relation to each other. Transformation explains the relations between the parts, how one part becomes another. It describes the process involved in the changing nature of the parts. Each structure is also self-regulating, meaning that structures inherently seek self-maintenance, organization, and closure. A structural analysis of thought shows the development of such patterns of organization—that is, ordering, classification, setting up correspondences and relations, coordinating contradictions, and explaining transformations by interactions, reversibility, and compensation, et cetera. In fact, the development of structures, according to Piaget and several contemporary biologists, characterizes the growth process. Because of equilibration, the structure expands to include the “reach beyond the grasp,” but also seeks organization and closure, keeping the structure always “under construction.” Some scholars have argued that Piaget’s notion of structure relates more to mathematics and science thinking than to the development of literacy, the arts, or social science. However, structural shifts have been described in reading strategies (Chall, 1983; Ferreiro, 1984), in invented spelling strategies (Henderson, 1985), in writing development (Fosnot, 1989), in the arts (Goodnow, 1977; see also Gardner, 1985), and in the social sciences (Damon, 1977; Furth, 1980; Selman, 1980; see also Edwards, 1986). Although the main body of Piaget's work is centered on illuminating the progressive cognitive structuring of individuals, the effect of social interaction on learning was not overlooked by him. He wrote, "There is no longer any need to choose between the primacy of the social or that of the intellect; the collective intellect is the social equilibrium resulting from the interplay of the operations that enter into all cooperation" (1970, p. 114).

Mind, Consciousness, and Language

It was this dialectic between the individual and society, and thus the effect of social interaction, language, and culture on learning that became the main focus of Vygotsky's work. Like Piaget, he too believed learning to be developmental and constructive, but he differentiated between what he called "spontaneous" and "scientific" concepts. He defined spontaneous concepts as pseudoconcepts, those "emerging from the child's own reflections on everyday experience" (Kozulin, 1986). Vygotsky proposed that scientific concepts, on the other hand, originate in the structured activity of classroom instruction and impose on the child more formal abstractions and more logically defined concepts than those constructed spontaneously. He perceived them as culturally agreed upon, more formalized concepts. Having made this distinction between pseudoconcepts and scientific concepts, one of Vygotsky's main questions became, "What facilitates the learning that moves the child from spontaneous concepts to scientific concepts?" Rephrased from a biological perspective, the question becomes: If learning is a specific case of evolution, how is it that in the short time of a young learner's life, he or she comes to construct ideas that took humans centuries to develop?

Zone of Proximal Development

Vygotsky (1962/1986) argued that scientific concepts do not come to the learner in a ready-made form. They cannot be transmitted simply with language. They undergo substantial development depending on the existing level of the child's ability to comprehend the adult's model. Vygotsky believed that, whereas scientific concepts work their way "down," imposing their logic on the child, spontaneous concepts work their way "up," meeting the scientific concept and allowing the learner to accept its logic. In Vygotsky's words,

> Though scientific and spontaneous concepts develop in reverse directions, the two processes are closely connected. The development of a spontaneous concept must have reached a certain level for the child to be able to absorb a related scientific

> concept. For example, historical concepts can begin to develop only when the child's everyday concept of the past is sufficiently differentiated—when his own life and the life of those around him can be fitted into the elementary generalization "in the past and now"; his geographic and sociological concepts must grow out of the simple schema "here and elsewhere." In working its slow way upward, an everyday concept clears a path for the scientific concept and its downward development. It creates a series of structures necessary for the evolution of a concept's more primitive, elementary aspects, which give it body and vitality. Scientific concepts, in turn, supply structures for the upward consciousness and deliberate use. Scientific concepts grow downward through spontaneous concepts; spontaneous concepts grow upward through scientific concepts. (1962/1986, p. 194)

Vygotsky used the term "zo-ped," zone of proximal development, to describe the place where a child's spontaneous concepts meet the "systematicity and logic of adult reasoning" (Kozulin, 1986, p. xxxv). This zone varies from child to child and reflects the ability of the learner to understand the logic of the scientific concept. For this reason, Vygotsky viewed tests or school tasks that only looked at the child's individual problem solving as inadequate, and argued instead that the progress in concept formation achieved by the child in cooperation with an adult was a much more viable way to look at the capabilities of learners.

Inner Speech

Early in his career, Piaget had studied the language of preschoolers and concluded that much of their language was egocentric in nature—that they spoke aloud, but to themselves rather than for any social communicative purpose. Vygotsky repeated many of Piaget's early experiments on language and concluded instead that speech was social right from the start. He proposed that "egocentric speech" was actually the beginning of the formation of the inner speech that would be used later as a tool in thinking. For Vygotsky, this was a case of how the outward interpsychological relations become the inner intrapsychological mental functions … how culturally prescribed forms of language and reasoning find their individualized realization … how culturally sanctioned symbolic systems are remodeled into individual verbal thought (Kozulin, 1986). Inner speech, to Vygotsky, also played a role in the formation of spontaneous concepts. He proposed that spontaneous concepts have two components, a concept-in-itself and the concept-for-others, the former designating the part of the concept dependent on an organization of actions, the latter describing the concept put to speech in order to communicate it to others. These two components provide a dialectical tension right from the start as the child struggles to represent concepts in action with culturally appropriate symbols in order to communicate them to others. This process prepares the way for the zone of proximal development. In Vygotsky's words,

> The double nature of the pseudoconcept predetermines its specific genetic role. The pseudoconcept serves as a connecting link between thinking in complexes and thinking in concepts. It is dual in nature: a complex already carrying the germinating seed of a concept. Verbal communication with adults thus becomes a powerful factor in the development of the child's concepts. The transition from thinking in complexes to thinking in concepts passes unnoticed by the child because his pseudoconcepts already coincide in content with adult concepts. Thus the child begins to operate with concepts, to practice conceptual thinking, before he is clearly aware of the nature of these operations. (1986, p. 124)

Whereas Piaget sought to study and illuminate the role of contradiction and equilibration in learning, Vygotsky sought to study dialogue. He was not only interested in the role of inner speech on the learning of concepts, but on the role of the adult and the learners' peers as they conversed, questioned, explained, and negotiated meaning. He argued that "the most effective learning occurs when the adult draws the child out to the jointly constructed 'potential' level of performance" (Bickmore-Brand & Gawned, 1993, p. 49). Other psychologists (Bruner & Ratner, 1978; Ninio & Bruner, 1978) extended this work on dialogics and proposed the notion of "scaffolding." Studying mother-infant dyads during face-to-face interactions, these researchers focused on and described the communication ritual that occurred in the turn-taking dialogue with the mother at times imitating the baby, but then varying the response slightly to stretch and challenge the child's response. In spite of the difference in language abilities, the two were seen as jointly constructing meaning. Wells (1981) has noted that this scaffolding process continues throughout early language development and the child appears to internalize the adult role and eventually directs herself using the same cues.

Some Considerations

Vygotsky's notion of scientific concepts working downward, while spontaneous concepts work upward—the zone of proximal development—is controversial for some constructivists, as Cobb will further elaborate in Chapter 3. Is the "scientific" concept being viewed as "truth" in the objective sense, and the teacher's role being perceived of as one that facilitates learner's adoption of it? Is an assumption being made that a learner can "absorb" the adult's conceptual understanding if the developmental match is right—that meaning resides in the symbolic representation of the teacher and that it can be “transmitted” to a learner? These assumptions are not based on the new paradigm, but instead are a residue of the old. They are still grounded in an empiricist theory of learning and are based on a belief that we hold identical objective meanings about a world we are discovering, rather than constructing. The same point can be made about the notion of scaffolding in an educational setting. Is there a “truth” that the scaffolding process leads to? Whose truth is it? Some educators have called for a scaffolding process that is grounded in modeling theory and direct instruction, albeit at developmentally appropriate times (Bruner & Ratner, 1978; Cazden, 1983); while others place more emphasis on the child’s cognizing and see the scaffolding only as giving the child new possibilities to consider (Graves, 1983). Bruner (1986), for example, arguing for the former approach, suggests that scaffolding should provide “the child with hints and props that allow him to begin a new climb, guiding the child in next steps before the child is capable of appreciating their significance on his own.” According to Bruner, “It is the loan of the [adult’s] consciousness that gets the child through the zone of proximal development” (p. 132). Cambourne (1988), on the other hand, places less emphasis on modeling and more on the constructive nature of learning. He describes scaffolding as “raising the ante” and he fleshes out what he sees as the most common attributes in a conversation helpful to learning: (1) focusing on a learner’s conception; (2) extending or challenging the conception; (3) refocusing by encouraging clarification; and (4) redirecting by offering new possibilities for consideration. For readers interested in the debate on scaffolding, Bickmore-Brand and Gawned (1993) offer a nice overview.

Representation as a Constructive, Evolutionary Act

Although Vygotsky’s notions of internalization and appropriation are somewhat problematic to constructivists, his focus on the dialectical interplay between symbol and thought in concept development provided a fertile ground for research. What is the interplay between language and thought? Is language just a symbolic representation of previously constructed ideas, or does language actually affect thought? Answers to these questions have been controversial, and often even contradictory; thus, many questions still remain. For example, Vygotsky and Luria studied illiterate peasants in rural Soviet Central Asia and found that their speech and reasoning echoed patterns of practical, situational activity, while for people with some formal education the relation was reversed: abstract categories and word meanings dominated situational experience and restructured it (Luria, 1976). This work suggested that symbolic representation actually affected thought. Work by Lave (1988) in mathematics produced opposite results, however—schooling in abstract mathematics showed little connection to approaches used to solve mathematical problems in context. Educated and uneducated alike solved grocery problems in similar ways and these solutions showed no connection to abstractions learned in school. Similarly, Sinclair (1973) found that conservers used comparative language (i.e., taller than, shorter than) to describe the tall-thin and short-fat beakers used in the conservation of liquid task, whereas nonconservers did not; therefore, she taught nonconservers to use the terms to see if the comparative concept embedded in the words would have an effect on the development of conservation. No significant effect was found. Although the effects of language and abstract formalisms do not seem to be direct, there does seem to be an interaction between symbol and thought when one compares representation across media, such as language, dance, music, or drawing. For example, different features of a cup are depicted depending on whether one is representing symbolically in clay, with pencil and paper, or with language. In clay, the most important feature to symbolize appears to be the contour and the volume of the container; with pencil and paper, the handle and side are depicted; with language, subjects described the function of a cup (Olson, 1970). The very act of representing objects, interactions, or meaning embedded in experience, within a medium such as language, paint and canvas, or mathematical model appears to create a dialectical tension beneficial to thought. Each medium has its own attributes and limits and thus produces new constructions, new variations on the contextually embedded meaning (Eisner, 1993; McLuhan, 1964; Olson, 1970). For example, Sherman (1978) demonstrated how the choice of art medium (Styrofoam vs. clay) affects what children represent; with Styrofoam, buildings are more likely to be represented; with clay, people and animals. Golomb's (1974) work shows how the art medium (clay vs. paper and pencil) affects the details that get represented; when using clay to make people, different body parts are included than when paper and pencil are used. And Ives (1980) has argued convincingly that the use of photographs versus language produces different perspective-taking ability. In fact, it was this very point—the beneficial effect of the act of representing on thought—that led the sculptor Henry Moore to write, "I always draw something to learn more about it," and the writer Donald Murray to comment, "I write to surprise myself." Nelson Goodman (1978, 1984) pushes this issue even further, arguing that there is no unique "real world" that preexists independently of human mental activity. Instead, what we call the world is a product of minds whose symbolic procedures construct the world by interpreting, organizing, and transforming prior worldviews, thereby constructing new symbols. For

Goodman, the difference between the arts and sciences, for example, is not subjectivity versus objectivity, but the difference in constructional activities and the symbolic systems that result. Howard Gardner (working with Nelson Goodman at Harvard Project Zero) researched the development of early symbolization to characterize the different modes of operation by which intelligence expresses itself. In *Frames of Mind* (1985) he presents evidence for multiple, different "intelligences" that are the result of "minds which become specialized to deal in verbal or mathematical or spatial forms of world making, supported by symbolic means provided by cultures which themselves specialize in their preference for different kinds of worlds" (Bruner, 1986, p. 103). Thus the world a musician builds using a symbolic system that employs rhythm, cadence, and tone is indeed a different world than the one constructed by a visual artist employing space, line, repleteness, and color. Language, too, becomes its own context, for it involves the uses of signs to organize and plan sign-using activity itself. And this building process is developmental because constructions within a medium serve as building blocks to new constructions. Domains of discourse that we generate become part of our existence and constitute the environment with which we couple. Just as single-cell organisms couple with their "surround" symbiotically via activity and self-organization (Kauffman, 1993), humans do so in communities of discourse for identity and adaptation—a natural process of evolution. Maturana and Varela describe it well:

> We humans, as humans, exist in the network of structural couplings that we continually weave through the permanent linguistic trophallaxis of our behavior. Language was never invented by anyone only to take in an outside world. Rather it is by languaging that the act of knowing, in the behavioral coordination which is language, brings forth a world. (Maturana & Varela, 1998, p. 234)

A Synthesis: Knowledge as Construction

The biological landscape characterized by autopoetic systems and dissipative structures, and the cognitive theories of Piaget, Vygotsky, and others provide a basis for a psychological theory of learning called constructivism. Implied is the position that we as human beings have no access to an objective reality since we are constructing our version of it, while at the same time transforming it and ourselves. Widespread interest in constructivism over the last decade led to a debate between those that place more emphasis on the individual cognitive structuring process and those that emphasize the social and cultural effects on learning (Fosnot, 1993; O'Loughlin, 1992; Steffe & Gale, 1995).

Terms like “cognitive constructivism” and “social constructivism” have become common in the literature, and even within these perspectives there is a plethora of definitions, depending on, as Simon (1993) points out, “whether the social or the cognitive is viewed as figure or ground” (p. 4). The important question to be asked is not whether the cognizing individual or the culture should be given priority in an analysis of learning, but instead, What is the interplay between them? When physicists (i.e., Heisenberg, Bohr) studied the particulate nature of the atom, they concluded that subatomic particles have no meaning as isolated entities. To the extent that a particle can be studied in terms of its placement in the atom, the momentum becomes ambiguous, and vice versa. Particles are now understood as waves dancing between states of mass and energy. In the words of Neil Bohr, “Isolated material particles are abstractions, their properties being definable and observable only through their interaction with other systems” (cited in Capra, 1982, p. 124). Contemporary biologists once again agree. We quote from a chapter entitled “New Biology versus Old Ideology.” The biological and the social are not separable, antithetical, or alternatives, but rather are complementary. All causes of the behavior of organisms, in the temporal sense to which we should restrict the term *cause*, are simultaneously both social and biological, as they are all amenable to analysis at many levels. All human phenomena are not “causes” of those phenomena but merely “descriptions” of them at particular levels, in particular scientific languages (Lewontin, Rose, & Kamin, 1984, p. 282).

So, too, with cognition. We cannot understand an individual’s cognitive structure without observing it interacting in a context, within a culture. But neither can we understand culture as an isolated entity affecting the structure, since all knowledge within the culture is only, to use Cobb’s terminology, “taken-as-shared” (Cobb, Yackel, & Wood, 1992). Since the process of construction is adaptive in nature and requires self-reorganization, cultural knowledge that is assumed to be held by members of the culture is in reality only a dynamically evolving, negotiated interaction of individual interpretations, transformations, and constructions. At most, cultural knowledge can only be assumed, or “taken-as-shared,” by its members. Yet cultural knowledge is a whole larger than the sum of the individual cognitions. It has a structure of its own which interacts with the individuals who are also constructing it. Current biological models help us understand that both the structure of the mind and the knowledge we construct of the world are a part of an open system—in fact, knowledge and mind cannot be separated because one affects the other. Both are being developed as the natural outcomes of the evolution of autopoetic systems characterized by dissipative structures (this includes the social world). Thus, in contrast to the maturationists who believed that development determines what one can “know” and how one “knows” it, to constructivists learning *is* development. Oatley explains this interaction:

> What kind of adaptation to the world is the human one? It is an adaptation that succeeds in transforming the environment. It involves social cultures which shape social selves by their rules; cultures which are themselves shaped by changes in the rules that people create … Our constructions of the physical and social world are not static. They continue to change. Part of our mental ontogeny might even be affected by the study we make of it. As an analogy one might imagine a computer program whose function is to rewrite itself in the light of its discovery of how it is working. This recursiveness is, I will argue also, an important aspect of conscious mind. In order to do justice to the brain and its mechanisms we need to have an account of such schemata, which can turn round upon themselves—which consider their own constitution and transform themselves. (1985, pp. 32–33)

We do not act alone; humans are social beings. Throughout our evolution, from the hunter-gatherer days to the technological present, we have sought to establish communities, societies, forms of communication, and thus cultures as an adaptive mechanism. We attempt to survive collectively, rather than individually; we procreate, communicate, and teach our young. Indeed, Harlow’s (1950) classical study of chimpanzees demonstrated that attachment was an innate survival need. The infant chimpanzees in his now-famous study preferred the cloth-covered surrogate mothers over the wire mother, regardless of which one supplied food, and to these cloth-covered surrogates they clung and vocalized, especially when frightened. Without the surrogates, some died; others were frightened, irritable, and reluctant to eat or play; and peer contact among infant monkeys at least partially compensated for the deprivation of the mother (Coster 1972, cited in Craig, 1986). Social deprivation in humans has also been found to produce apathy, withdrawal, and general depressed functioning (Bowlby, 1960). Why is social interaction basic? If learning is a case of self-organization and internal restructuring, then what role do language and the community play in its development? Direct transmission, modeling, reinforcement—all principles of learning implied from the old psychology paradigms that have been proposed at one time or another to explain the role of the social environment—become insufficient to explain cognitive restructuring, given our new view of learning. Some evolutionary biologists and neuropsychologists have argued that the encephalization of the brain (and the resulting ability for mental imagery and highly developed language forms) was an adaptation that was viable in that it enabled *Homo sapiens* to make major social changes (Oatley, 1985). According to Maturana and Varela (1998), “Consciousness and mind belong to the realm of ‘social coupling’ and the domains of discourse that we generate become part of our domain of existence and constitute part of the environment in which we conserve identity and adaptation” (p. 234). The ability to envision and construct tools for cultivation of food led to civilization—the development of fixed communities. Today, mass communication and transportation systems provide the potential for inhabitants of this planet to see themselves as a diverse unity. Representation, cognition, and social change are thus inherently connected. Again to quote Oatley,

> A major function of the human brain is indeed to sustain complex structures of knowledge of the physical world, and also of plans and purposes in the social world. It is the ability to create these structures which I will call schemata, to make inferences within them, and to reuse them symbolically for new purposes in metaphors, that provides the foundation for our peculiar human adaptation. (1985, p. 32)

Vygotsky’s emphasis on the sociohistorical aspect of knowledge—how it is that intuitive notions give way to more culturally accepted notions—makes sense from the perspective of this interplay. The culture and collective individuals within it create a “languaging of lived experience” such that the individual is disequilibrated; but reciprocally the culture is disequilibrated by individuals as they construct their environment. Thus, individual thought progresses toward culturally “accepted” ideas, but always in an open dynamic structure capable of creative innovation.

The Role of Representation

All cultures represent the meaning of experience in some way: through symbol, music, myth, storytelling, art, language, film, explanatory “scientific” models, and/or mathematical forms. Abstracting and generalizing experience by representing them with symbols (itself a constructive process) allows the creation of “semiotic spaces” where we can negotiate meaning (Wertsch, 1991). We may not understand in the same way as other humans who have had different experiences, but by using language, stories, and metaphors and models, we can listen to and probe each other’s understanding, thereby negotiating and constructing “taken-as-shared” meanings (Blumer, 1969; Mead, 1934). Constructing symbolic representations empowers us to go beyond the immediacy of the concrete, to cross cultural barriers, to encounter multiple perspectives that generate new possibilities, to become conscious of our actions on the world in order to gain new knowledge with which to act. As we attempt to generalize meaning across experiences, “tugs and pulls” may occur—a pull toward categorization, classification, ordering, connecting—the primacy toward correspondences and affirmations that Piaget describes. On the other hand, the construction of this generalization in a symbolic form within a medium creates a tug on the individual experience highlighting the differences between it and the symbolic generalization. This “tug and pull” is the intrinsic motivating force in reflective abstraction. In other words, reflection on these representations—themselves decentered constructions—may bring about new insights, new constructions, new possibilities, when one subsequently returns to reflecting on the experience. The act of representation is what makes us human. The reptilian brain, for example, is reactive and associative in nature; perceptual stimuli cause reflexive action. In humans, myelination of the visual cortex and the development of the cerebral cortex allow us to have mental images of objects and actions on them (Malerstein, 1986; Oakley, 1985) and this ability to represent allows us to reflect on our actions, consider multiple perspectives simultaneously, and to even think about our thinking. Vocal tract structures and the capacity of the brain for language development also have been acquired over time by biological evolution. How does individual representation interface with one’s social setting? As ideas are shared within a community, the “surround” (Kauffman, 1993) may intensify individual cognitive activity. Multiple perspectives may offer a new set of correspondences, and at times even contradictions, to individual constructions. Of course, these perspectives shared by others are not “transmitted”; even the shared perspectives are interpreted and transformed by the cognizing individual. But as we seek to organize experience for generalization and communication, we strive to coordinate perspectives, to “get into the head” of others—to attach, thereby constructing further reflective abstractions and developing “taken-as-shared” meanings. From this perspective, learning is a constructive building process of meaning making which results in reflective abstractions producing symbols within a medium. These symbols then become part of the individual’s repertoire of assimilatory schemes, which in turn are used when perceiving and further conceiving. For example, a waterfall sparkling in broad daylight and a waterfall at dusk are seen as “waterfalls” even though the light rays hitting the retina are very different. The linguistic symbol “waterfall” represents a reflective abstraction that is the result of a generalization of lived experiences with past waterfalls, but it is then used in perception, selectively, as we isolate stimuli from the environment, transforming and organizing phenomena for coherence and meaning. The medium that is used in the representation as we attempt to communicate our meaning to the community also has an effect on the symbol. A waterfall represented musically may involve cadences, harmonies, and rhythm; represented in dance, turns, twists, and leaps; in the visual arts, form, line, and texture; in the sciences, forces, interactions, continuities, and discontinuities. Meanings, indeed "worldviews," may be unique to the cognizing, self-regulating individual but that is not to say that they are idiosyncratic, nor disconnected to context or the environmental surround: First, because the symbols themselves used in cognizing are the result of previous "taken-as-shared" meanings by a community—and thus are linked to culture right from the start; and secondly, because when the new constructions are justified and communicated to the community they are done so with accepted forms of proof, argument, and justification determined by communities of practice and discourse. What holds up as a good question, a good justification, and a good explanation, and how data are measured, interpreted, and modeled all evolve from interactions in these communities. As they are further reflected upon and discussed, a process that is likely to generate both further possibilities and contradictions, newly constructed, temporary, "taken-as-shared" meanings are consensually agreed upon as viable. This process has been represented by Fosnot [editor's note: in the first edition of this book, 1996, Chapter 2] as a dialectical tripartite model, depicted in Figure 2.3.

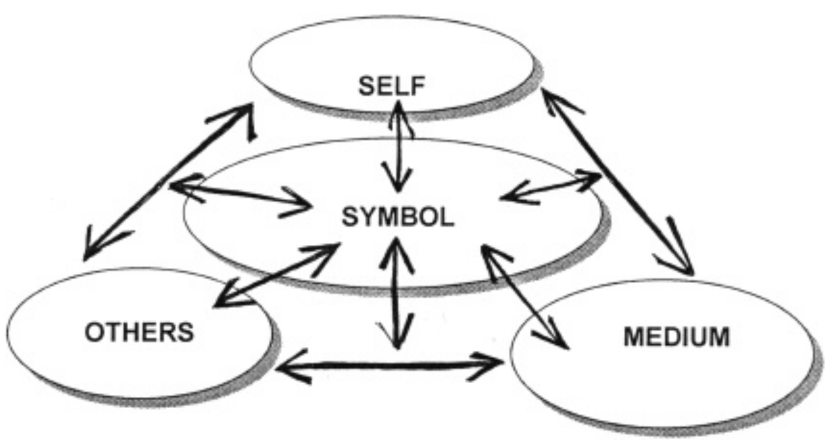

FIGURE 2.3. Constructivist learning model.

The cognizing individual generates possibilities and contradictions when structures are perturbed. In attempting to represent these reflective abstractions in a medium, to make them conscious and to communicate them to others, further tugs occur. But the process is not linear. Indeed, language is almost too linear a medium to use to describe the transactional nature of the interplay. For "others" are other cognizing individuals, therefore a composite of constantly shifting and evolving ideas—not a static entity but a dynamic one. Further, the cognizing individual is operating with cultural symbols that are derived from past negotiated "taken-as-shared" social and cultural meanings. Nor is the medium static: While each medium has limits and features that affect the symbols, as humans create within media they push against these limits and formulate new features. Just as in the vases and the faces in the trick figure–ground pictures, the components are complementary. In fact, they are only perceivable when we organize the picture in one fashion or another. Or as Heisenberg pointed out in relation to particles and their momentum many years ago, the question determines the answer. If we ask a question about the affect of culture on cognition, we get a cultural answer; if we ask about the individual's cognizing we get an answer that reflects that component. In reality, even the components are constructs of human-made worlds. Perhaps the most that can be said is that the striving for symbolic representation and coherent meaning-making with other humans is a spiraling dynamic "dance" of interaction and evolution, a search for equilibrium—a self-organizing criticality (Bak, 1996). From this perspective, living itself is defined as knowing (Deutsch, 1997; Perry & Kolb, 2003). The new paradigm demands, in the words of Bruner (1986, p. 105), that we "abandon the idea that 'the world' is there, once, for all, and immutably, [and that we] substitute for it the idea that what we take as the world is itself no more nor less than a stipulation couched in a symbol system."

APPLICATION OF CONSTRUCTIVISM TO EDUCATION

Constructivism is a theory about learning, not a description of teaching. No "cookbook teaching style" or pat set of instructional techniques can be abstracted from the theory and proposed as a constructivist approach to teaching. Some general principles of learning derived from constructivism may be helpful to keep in mind, however, as we rethink and reform our educational practices.

- Learning is not the result of development; learning *is* development. It requires invention and self-organization on the part of the learner. Thus, teachers need to allow learners to raise their own questions, generate their own hypotheses and models as possibilities, test them out for viability, and defend and discuss them in communities of discourse and practice.
- Disequilibrium facilitates learning. "Errors" need to be perceived as a result of learners' conceptions, and therefore not minimized or avoided. Challenging, open-ended investigations in realistic, meaningful contexts need to be offered which allow learners to explore and generate many

possibilities, both affirming and contradictory. Contradictions, in particular, need to be illuminated, explored, and discussed.

- Reflective abstraction is the driving force of learning. As meaning makers, humans seek to organize and generalize across experiences in a representational form. Allowing reflection time through journal writing, representation in multisymbolic form, and/or discussing connections across experiences or strategies may facilitate reflective abstraction.
- Dialogue within a community engenders further thinking. The classroom needs to be seen as a "community of discourse engaged in activity, reflection, and conversation" (Fosnot, 1989). The learners (rather than the teacher) are responsible for defending, proving, justifying, and communicating their ideas to the classroom community. Ideas are accepted as truth only insofar as they make sense to the community and thus they rise to the level of "taken-as-shared."

Learning is the result of activity and self-organization and proceeds toward the development of structures. As learners struggle to make meaning, progressive structural shifts in perspective are constructed—in a sense, "big ideas" (Schifter & Fosnot, 1993). These "big ideas" are learner-constructed, central organizing principles that can be generalized across experiences, and which often require the undoing or reorganizing of earlier conceptions. This process continues throughout development.

CONCLUSION

Constructivism is a poststructuralist psychological theory (Doll, 1993), one that construes learning as an interpretive, recursive, nonlinear building process by active learners interacting with their surround—the physical and social world. It is a psychological theory of learning that describes how structures, language, activity, and meaning-making come about, rather than one that simply characterizes the structures and stages of thought, or one that isolates behaviors learned through reinforcement. It is a theory based on complexity models of evolution and development. The challenge for educators is to determine what this new paradigm brings to the practice of teaching.

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