7. CONSTRUCTIVISM: IMPLICATIONS FOR THE DESIGN AND DELIVERY OF INSTRUCTION[1]

Thomas M. Duffy **Donald J. Cunningham**

INDIANA UNIVERSITY

Instruction should be designed to support a dialogue between the child and his or her future; not a dialogue between the child and the adult's history. Adult wisdom does not provide a teleology for child development.

— Adapted from Griffin and Cole's discussion (1984) of the zone of proximal development.

7.1 INTRODUCTION[1]

Constructivism! The increase in frequency with which this word appears in the discourse of educational research, theory, and policy is truly remarkable. Unfortunately much of the discussion is at the level of slogan and cliché, even bromide. "Students should construct their own knowledge" is being reverentially chanted throughout the halls of many a school/college/department of education these days, and any approach that is other than constructivist is characterized as promoting passive, rote, and sterile learning. For example, consider Rogoff's (1994) description of what she calls the *adult-run* model of how learning occurs:

> . . . learning is seen as a product of teaching or of adults' provision of information. Adults see themselves as responsible for filling children up with knowledge, as if children are receptacles and knowledge is a product. . . . [The] children are seen as receivers of a body of knowledge, but not active participants in learning. The children have little role except to be receptive, as if they could just open a little bottle cap to let adults pour the knowledge in. In this adult-run model, adults have to be concerned with how to package the knowledge and how to motivate the children to make themselves receptive (p. 211).

We wonder how many, if any, educators would recognize themselves in this description.[2] Perhaps the proponents of programmed instruction? Skinner would certainly reject the aspersion:

> A good program of instruction guarantees a great deal of successful action. Students do not need to have a natural interest in what they are doing, and subject matters do not need to be dressed up to attract attention. No one really cares whether PacMan gobbles up all those little spots on the screen. . . . What is reinforcing is successful play, and in a well-designed instructional program students gobble up their assignments (1984, p. 949).

Skinner goes on to describe a classroom in which the students are so volubly engaged with the instruction on their "teaching machine" that they don't even look up when the teacher makes distracting noises by jumping up and down on the teacher's platform at the front of the room.

It may be time to move beyond the paradigm debates of the last few years for precisely the reason that the tendency to sort the various approaches into "Good Guys" and "Bad Guys" (Cunningham, 1986) has not led in profitable directions. Skinner and his advocates see themselves as virtuous as any constructivist (see 2.5.2)! The debates have focused on *method*, as in whether we should use a problem-based method, or cooperative groups, or hypermedia databases, or programmed instruction, etc. For some, the paradigm issue

[1] The development of this paper was supported in part through T. M. Duffy's contract with the North Central Regional Education Laboratory. The views expressed in this paper, however, do not necessarily reflect the views of the Laboratory.

[2] Modesty prevents us from mentioning our own tendency toward this sort of hyperbole!

has reached the status of the utterly irrelevant; we should ignore theoretical issues and simply pick the methods that *work*, that reliably and efficiently lead to student learning.

What we see as crucial in these debates, however, is scarcely acknowledged: a fundamental difference in world view, disagreement at the level of *grounding assumptions*, the fundamental assumptions underlying our conception of the teaching-learning process. It must be recognized that grounding assumptions are always *assumed*, that they can never be proved unambiguously true or false. We may and certainly will provide evidence and try to persuade you that our assumptions are reasonable and those to which you should commit. An important part of our argument will be that these assumptions lead to demonstrably different goals, strategies, and embodiments of instruction, even when there are some superficial similarities to instruction derived from different assumptions.

An immediate difficulty confronts us, however. The term *constructivism* has come to serve as an umbrella term for a wide diversity of views. It is well beyond our purposes in this chapter to detail these similarities and differences across the many theories claiming some kinship to constructivism. However, they do seem to be committed to the general view that (1) learning is an active process of constructing rather than acquiring knowledge, and (2) instruction is a process of supporting that construction rather than communicating knowledge. The differences, some quite pronounced, are in definitions of such terms as *knowledge*, *learning*, and *construction*, and about the processes appropriate for supporting learning. For example, within Rogoff's (1994) distinction between three instructional approaches—(1) adult-run (transmission from experts to novices), (2) children-run (individual or collaborative discovery), or (3) community of learners (transformed participation in collective sociocultural experience)—one can see possibilities of both constructivist and nonconstructivist instruction. So, for example, reciprocal teaching (e.g., Palinscar & Brown, 1984) is often cited as a constructivist teaching strategy, yet it is very much teacher led. Similarly, group problem-based learning interventions (Savery & Duffy, 1995) might focus on the individual achievement of prescribed learning outcomes rather than on any sort of pattern of collective participation.

As the quote from Skinner suggests, everyone agrees that learning involves activity and a context, including the availability of information in some content domain. Traditionally in instruction, we have focused on the information presented or available for learning and have seen the activity of the learner as a vehicle for moving that information into the head. Hence the activity is a matter of processing the information. The constructivists, however, view the learning as the activity in context. The situation as a whole must be examined and understood in order to understand the learning. Rather than the content domain sitting as central, with activity and the "rest" of the context serving a supporting role, the entire gestalt is integral to what is learned.

An implication of this view of learning as constructed in the activity of the learner is that the individual can only know what he or she has constructed—and we cannot "know" in any complete sense of that term what someone else has constructed. This implication has led to considerable debate among many individuals seeking to understand constructivism. In particular we hear the reaction that constructivism leads inevitably to subjectivism, to a relativism where anyone's constructions are as good as any one else's and where we are unable to judge the value or truth of constructions with any degree of certainty. As will be detailed below, constructivists typically substitute some notion of viability for certainty; that is, we judge the validity of someone's knowledge, understanding, explanation, or other action, not by reference to the extent to which it matches reality but, rather, by testing the extent to which it provides a viable, workable, acceptable action relative to potential alternatives. As Bruner has noted, asking the question "How does this view affect my view of the world or my commitments to it, surely does not lead to 'anything goes.' It may lead to an unpacking of suppositions, the better to explore one's commitments" (1990, p. 27).

A second concern has been that the idiosyncrasies of constructions lead to an inability to communicate. That is, how can we possibly talk to one another if our world constructions (meanings) are idiosyncratic based on our experience. Indeed, the lack of shared meaning can make communication very difficult for two people from very different cultures. Simple language translations do not do the trick; rather we must develop cultural understandings before we can communicate adequately, a lesson the business community has already learned in this increasingly global economy. For those of us who share a common culture, however, the communication is not that difficult. Indeed, cultures are defined by a set of common experiences and the agreement of a common set of values based on those experiences. As Bruner (1990) puts it, culture forms minds, and minds make value judgments.

But don't we have shared meaning within the culture? Is it possible to have shared meaning? We can only evaluate whether meaning is shared by testing the compatibility of our individual meanings: exploring implications, probing more deeply. Of course, no matter how much we probe, we can never be sure that the meaning is shared.[3] Thus, rather than assuming a shared meaning, within the constructivist framework there is a seeking of compatibility, a lack of contradiction between views (Rorty, 1989). We probe at deeper and deeper levels to determine where or if our understandings begin to diverge. There are two important implications of this constructivist framework. First, we do

[3]Though we are sure all of our readers have had the experience of wondering whether our conversational partner "really" understands what we are saying. We have this experience most often in discussing educational theory and concepts. No matter how often our conversational partners states that they understand and even make statements indicative of understanding, we wonder if they really understand the "full" or deeper meaning and implications of what we are saying.

not assume that we must have a common meaning, but rather we actively seek to understand the different perspectives. Second, from a learning perspective, we do not assume that the learner will "acquire" the expert's meaning, and hence we do not seek a transmission approach to instruction. Rather we seek to understand and challenge the learner's thinking.

The common ground of constructivism could be summarized by von Glasersfeld's statement: "Instead of presupposing knowledge is a representation of what exists, knowledge is a mapping, in the light of human experience, of what is feasible" (1989, p. 134).

7.1.1 A Brief Historical and Philosophical Context

Current research and theory in learning and instruction has far too often been presented in an historical framework, with a consequence that we fail to learn about the complexity of the issues and the potential pitfalls from previous work (Cuban, 1991). Constructivism certainly has a long history in education and philosophy, and there is much to be learned from that history. However, a review of that history could easily be a book in and of itself. As a consequence of the space available, it is with apologies that we can only offer a brief reference to these historical contexts.

Von Glasersfeld (1989) attributes the first constructivist theory to an Italian philosopher, Giambattista Vico, in the early 18th century. As described by Von Glasersfeld, "one of Vico's basic ideas was that epistemic agents can know nothing but the cognitive structures they themselves have put together . . . 'to know' means *to know how to make*." (1989, p. 123). While Vico has received little attention in current constructivist theory building, there are several 20th-century philosophers who provide significant epistemological grounding for the current constructivist views. Kuhn (1970), the later Wittgenstein (Malcomb, 1986), and Rorty (1991) are all frequently cited for their basic argument that knowledge is a construction by individuals and is relative to the current context (community), rather than representing some correspondence to external reality.

Kuhn (1970), of course, has made this point most strongly in considering theory and research in science. His *Structure of Scientific Revolution* (Kuhn, 1970) provided the grounding for a major paradigm shift in science toward a "best description" view of theory rather than an approximation to the "truth." In essence, he argued that the meaning of our vocabulary resides in our theory rather than outside of it. Thus, there is no metavocabulary that sits independent of theory, and, as such, it is impossible to translate between theories. That is, theories provide their own lens into the world, with each theory providing a different lens (or perspective). For example, Kuhn argues that there is no independent way to reconstruct phrases like "really there." All "facts" are theory laden.

Wittgenstein (Malcom, 1986) took a similar position in his study of language, forsaking his initial logical positivist position (i.e., that words can be fully defined by their correspondence to objects) to argue for the total context dependency of meaning. Hence, he argued that as we crisscross the landscape of contexts for a word, it will continually become richer and richer in meaning.

The pragmatic theory of Richard Rorty (1991) has played a particularly significant role in the theoretical work of those constructivists most interested in the cognitive development of the individual in society. Rorty's pragmatism holds that "knowledge is not a matter of getting it right but rather acquiring habits of action for coping with reality" (1991, p. 1). Thus, rather than seeking "truth" by correspondence to the real world, we seek viability, i.e., explanations that are viable in the world as we understand it. We are always seeking to increase the viability of our understanding, both by improving our account of specific events or experiences and by interweaving our explanations, thus weaving a web of understanding.

Rorty argues that viability is culturally determined; knowledge and understanding are ethnocentric, and viability is established through obtaining unforced agreement within the community.[4] Thus knowledge (or fact) and opinion are distinguished not by their "truth" value, but rather by the ease with which one can obtain agreement in the community. Rorty points out that if we can set aside the desire for objectivity, we can change our self-image from one of "finding" to one of "making." Knowledge is in the constructive process rather than a finding: The culture defines and is defined by what it agrees is "known."

While Rorty describes the construction of knowledge as the seeking of unforced agreement within the community, the focus is not so much on the agreement as it is on the dialogical process involved in seeking understanding:

> We cannot, I think, imagine a moment at which the human race could settle back and say, "Well, now that we've arrived at the Truth we can relax." We should relish the thought that the sciences as well as the arts will *always* provide a spectacle of fierce competition between alternative theories, movements, and schools. The end of human activity is not rest, but rather richer and better human activity (Rorty, 1991, p. 39).

For example, science is not "better" than the arts or everyday problem-solving activity because it is discovering the truth, but rather because it has rules of discourse that support and focus on the seeking of unforced agreement (Bereiter, 1994). As Rorty puts it, ". . . the only sense in which science is exemplary is that it is a model of human solidarity" (1991, p. 39). Bereiter (1994) has argued that

[4] *Community* simply refers to the fact that knowledge is socially determined: Someone must agree with your assertion before it is counted as knowledgeable. To the extent that you increase the size of the community that is in unforced agreement, you have accounted for or accommodated more alternative perspectives, and hence you have expanded the web of understanding. Thus, in seeking unforced agreement, while we may start small, in our circle of colleagues, we are constantly seeking a wider spectrum of the community to come into some level of agreement with our propositions.

this "solidarity" rests in four key commitments in science. These are commitments to :

- Work toward common understanding satisfactory to all.
- Frame questions and propositions in ways that permit evidence to be brought to bear on them.
- Expand the body of collectively valid propositions.
- Allow any belief to be subject to criticism if it will advance the discourse.

To say that we think we are going in the right direction is simply to say that we can look back on the past and describe it as progress. That is, rather than moving closer to the truth, we are able to interweave and explain more and more. Rorty claims, for example, that the pragmatists' distinction between knowledge and opinion, ". . . is simply the distinction between topics on which agreement is relatively easy to get and topics on which agreement is relatively difficult to get" (1991, p. 23).

Philosophy is only one discipline that has relevance to constructivism in its application to instruction. There are views from a wide range of other disciplines that reflect the epistemological and methodological stances that are compatible with constructivism that we simply do not have the space to pursue in this chapter, e.g., semiotics (Cunningham, 1992), biology (Maturana & Varela, 1992), structuralism (Hawkes, 1977), and postmodernism (Lemke, 1994; Hlynka & Belland, 1991).

The philosophers, themselves, generally did not directly address the educational implications of their views. Rather, we see parallel developments in pedagogical theory and practice. Thus, while Vico published his work in the early 18th century, in the middle part of that century (1760) Jean Jaques Rousseau published *Émile* (Rousseau, 1955), a treatise on education in which he argued that the senses were the basis of intellectual development and that the child's interaction with the environment was the basis for constructing understanding (Page, 1990). Thus Rousseau emphasized learning by doing with the teacher's role being that of presenting problems that would stimulate curiosity and promote learning. Rousseau's views were in direct opposition to the existing educational framework in which the focus was on study and memorization of the classics. His treatise came shortly before the French Revolution and served as the basis for educational reform in France after the revolution.

John Dewey (1916, 1929, 1938) was perhaps the greatest proponent of situated learning and learning by doing. Dewey, like Rousseau, reacted against the traditional educational framework of memorization and recitation and argued that "education is not preparation for life, it is life itself." Also like Rousseau, Dewey was responding to the need for restructuring education to meet the changing needs of society, in this case the start of the Industrial Age in America and the demands of industrial technology. Dewey argued that life, including the vocations, should form the basic context for learning. In essence, rather than learning vocations, we learned science, math, literature, etc., through vocations (Kliebard, 1986). This is similar to the current argument for "anchored instruction" in which the learning of any subject is anchored in a larger community or social context (CTGV, 1992).

Most importantly, learning was organized around the individual rather than around subject-matter topics and predetermined organizations of domains. Dewey emphasized perturbations of the individual's understanding as the stimulus for learning (Rochelle, 1992). In essence, the learner's interest in an issue had to be aroused, and learning was then organized around the learner's active effort to resolve that issue. Dewey's focus was on an inquiry-based approached to learning, for he saw scientific inquiry as a general model for reflective thinking (Kliebard, 1986). This is not to say that the learners were to learn the scientific method as a fixed procedure, but rather that they were to learn the problem-solving skills and informal reasoning associated with scientific work (see, for example, Bereiter, 1994).

In concluding this discussion of Dewey, we would like briefly to address the role of the teacher in this discussion of constructivist theory. While the focus of Rousseau, Dewey, and current constructivist educational theory is on the student's struggle with a problem, this should not be taken to suggest that there is no role for the teacher beyond developing and presenting problems. Indeed, as will be evident throughout this chapter, the teacher plays a central role, a role that we suspect is more central than in most instructional design frameworks. Dewey provides an eloquent statement on the issue:

> There is a present tendency in so-called advanced schools of educational thought . . . to say, in effect, let us surround pupils with materials, tools, appliances, etc., and let the pupils respond according to their own desires. Above all, let us not suggest any end or plan to the students; let us not suggest to them what they shall do, for that is unwarranted trespass upon their sacred intellectual individuality, since the essence of such individuality is to set up ends and means. Now, such a method is really stupid, for it attempts the impossible, which is always stupid, and it misconceives the conditions of independent thinking (Dewey in Page, 1990, p. 20).

Alfred North Whitehead also argued for a pedagogy reflective of the current constructivist theories. In his essay on the *Aims of Education*, Whitehead argued:

> Education is the acquisition of the art of the utilization of knowledge. . . . Interrelated truths are utilized *en bloc*, and the various propositions are employed in any order, and with any reiteration. Choose some important application of your theoretical subject; and study them concurrently with the systematic theoretical disposition (1929, p. 4).

Whitehead goes on to contrast this view of education with the prevailing approach:

> You take a textbook and make them learn it. . . . The child then knows how to solve a quadratic equation. But what is the point of teaching a child to solve a quadratic equation? There is a traditional answer to this question. It runs thus: The mind is an instrument; you first sharpen it and then use it. . . . solving the quadratic equation is part of sharpening

the mind. Now there is enough half-truths in that to have made it live through the ages. But for all its half-truths, it emphasizes a radical error which stifles the genius of the modern world. It is one of the most fatal, erroneous, and dangerous conceptions ever introduced into the theory of education. The mind is never passive; it is a perpetual activity. You cannot postpone its life until you have sharpened it. Whatever interest attaches to your subject matter must be evoked here and now; whatever powers you are strengthening in the pupil must be strengthened here and now; whatever possibilities of mental life your teaching should impart must be exhibited here and now. That is the golden rule of education, and a very difficult rule to follow (1929, pp. 5–6).

Like Rousseau and Dewey, Jerome Bruner saw learning in the activity of the learner (1966, 1971). In particular he emphasized discovery learning, focusing on the process of discovery in which the learner sought understanding of some issue. Within this context, Bruner emphasized that the issues or questions that guide the discovery process must be personally and societally relevant. Bruner's development of the social studies curriculum, *Man: A Course of Study* (MACOS), perhaps best exemplifies his theory. In designing this social studies curriculum for upper elementary students, Bruner and Dow summarize their overarching pedagogical view as:

> It is only in a trivial sense that one gives a course to "get something across," merely to impart information. There are better means to that end than teaching. Unless the learner also masters himself, disciplines his tastes, deepens his world view, the "something" that is gotten across is hardly worth the effort of transmission (undated, p. 3).

From that perspective, Bruner (1966) and his colleagues designed a social studies course that has as its goals that pupils:

- Have respect for and confidence in their powers of mind and extend that power to thinking about the human condition
- Are able to develop and apply workable models that make it easier to analyze the nature of the social world
- Develop a sense of respect for man as a species and to leave with a sense of the unfinished business of man's evolution

It should be clear from these goals that in Bruner's framework, knowledge is not in the content but in the activity of the person in the content domain. That is, the active struggling by the learner with issues *is* learning. Thus it was important for Bruner to begin the MACOS curriculum with the unknown as a means of stimulating the child's curiosity: In this case, it involved the study of baboon communities and the culture of the Nestlik Eskimos. This unknown was then related to the known, the child's familiar culture (family, school, etc.) in exploring the tool-making activities, language, social organizations, etc., as a mechanism for understanding both the unknown and the known. With this basic sequencing, the instructional methods used included: inquiry, experimentation, observation, interviewing, literature search, summarizing, defense of opinion, etc. (Hanley, Whitla, Moo & Walter, 1970). As this list suggests, the students were very much involved in the construction of their understanding, and the social interaction in the classroom was essential to that constructive process.

Bruner paid particular attention to aiding teachers in adapting to this new approach. In addition to extensive workshops, there was a variety of support materials. Video of students participating in sample lessons provided visual images of the patterns of activity that were being sought and highlighted problems. Model lessons were designed to address particularly difficult concepts; reading material for the teacher provided a "lively" account of the nature of the unit, discussing the "mystery" and why it impels curiosity and wonder; and a guide presented "hints" to teachers as to the kind of questions to ask, contrasts to invoke, and resources to use.

Evaluations of the MACOS curriculum indicated that it was successful in promoting inquiry and interpersonal interaction, increasing the children's confidence in expressing ideas and their ability to attend, and increasing the children's enjoyment of social studies (Hanley et al., 1970; Cole & Lacefield, 1980). The difficulty came in the acceptance of an inquiry-driven curriculum that did not "cover the basic content." Some teachers expressed concern that there was a neglect of traditional skills; and there was a fairly widespread public concern that the students should actually be exposed to diverse perspectives and be involved in inquiry that examined the basics tenets of our culture (Dow, 1975; Conlan, 1975). We suspect this to be a continuing struggle in any inquiry-based approach to instruction. Indeed, in spite of his tremendous philosophical influence on education, Dewey's schools were similarly short lived. Kliebard (1986) proposes that, as with Bruner's MACOS curriculum, teachers and the community felt uncomfortable with the lack of a well-defined content that students will "have" when they leave school, and thus the inquiry approach became increasingly constrained by detailed content specifications.

7.1.2 Current Views

Beyond this common framework of learning as situated in activity, constructivism has come to serve as an umbrella for a wide diversity of views. These views may lend particular emphasis to the role of the teacher as a manager or coach, as in reciprocal teaching (Palinscar & Brown, 1984) and many other apprentice frameworks. Alternatively, they may focus on the student and his or her ownership of the learning activity, as for example in the design of problem-based learning curricula (Savery & Duffy, 1995), in using student query as a mechanism for defining curriculum (Scardamalia & Bereiter, 1991), or any of the variety of other learner-centered approaches (see, for example, Brooks & Brooks, 1993). Finally, an increasingly dominant constructivist view focuses on the cultural embeddedness of learning, employing the methods and framework of

TABLE 7-1. CONTRASTS BETWEEN THE INDIVIDUAL COGNITIVE AND THE SOCIOCULTURAL CONSTRUCTIVIST VIEWS (adapted from Cobb, 1993)

	Cognitive Constructivist	Sociocultural Constructivist
The mind is located:	in the head	in the individual-in-social interaction
Learning is a process of:	active cognitive reorganization	acculturation into an established community of practice
Goal is to account for:	the social and cultural basis of personal experience	constitution of social and cultural processes by actively interpreting individuals
Theoretical attention is on:	individual psychological processes	social and cultural processes
Analysis of learning sees learning as:	cognitive self-organization, implicitly assuming that the child is participating in cultural practices	acculturation, implicitly assuming an actively constructing child
Focus of analyses:	building models of individual students' conceptual reorganization and by analyses of their joint constitution of the local social situation of development	individual's participation in culturally organized practices and face-to-face interactions
In looking at a classroom, we see:	an evolving microculture that is jointly constituted by the teacher and students	instantiation of the culturally organized practices of schooling
In looking at a group, we stress:	the heterogeneity and eschew analyses that single out pre-given social and cultural practices	the homogeneity of members of established communities and to eschew analyses of qualitative differences

cultural anthropology to examine how learning and cognition are distributed in the environment rather than stored in the head of an individual (Engstrom, 1993; Cole & Engstrom, 1993; Saxe, 1992; Cunningham & Knuth, 1993).

Cobb (1994a, 1994b) has attempted to characterize this diversity as representing two major trends that are often grouped together: individual cognitive and sociocultural (see Table 7-1). The individual cognitive approach derives from Piagetian theory (Piaget, 1977) and is closely associated with the current writings of Ernst von Glasersfeld (1984, 1989, 1992) and Cathy Fosnot (1989). This view emphasizes the constructive activity of the individual as he or she tries to make sense of the world. Learning is seen to occur when the learner's expectations are not met, and he or she must resolve the discrepancy between what was expected and what was actually encountered. Thus, the learning is in the individual's constructions as he or she attempts to resolve the conflict, or, alternatively put, individuals literally construct themselves and their world by accommodating to experiences. The conflict in Piagetian terms is known as *disequilibration*, but Dewey refers to the same stimulus as a *perturbation*. The first author has preferred the more neutral term *puzzlement* (Savery & Duffy, 1995). From this perspective, the importance of the teacher and other students is as a source of perturbation or puzzlement as a stimulus for the individual's learning. As von Glasersfeld (1989) notes, people, by far, offer the most effective and ready-at-hand source of perturbation of a learner's current understanding. Hence, within this framework, the focus is on the individual within the group, and cognition occurs in the head of the individual. In studying learning, we examine the impact of culture on the individual psychological processes.

In contrast to the von Glasersfeld/Piaget focus on individual constructions, the sociocultural approach emphasizes the socially and culturally situated context of cognition. Drawing on the insights of such theorists as Vygotsky, Leont'ev, and Bakhtin (e.g., see Wertsch, 1991), this approach examines the social origins of cognition, for example, the impact of an individual's appropriation of language as a mediating tool to construct meaning. Collective actions become the focus, as in Rogoff's (1994, p. 209) learning communities, where "learning occurs as people participate in shared endeavors with others, with all playing active but often asymmetrical roles in sociocultural activity." It is the changes of ways in which one participates in a community which are crucial, not individual constructions of that activity. Likewise, Driver and her colleagues (Driver, Asoko, Leach, Mortimer & Scott, 1994, p. 4) characterize learning science as "being initiated into ideas and practices of the scientific community and making these ideas and practices meaningful at an individual level." Learning, then, is a process of acculturation, and thus the study of social and cultural processes and artifacts is central.

While Cobb (1994b) argues that these two approaches are complimentary, we are not of one mind on this matter. While we will not argue the case here, it does seem that there is a contradiction between a position that posits development as increasingly abstract and formal constructions of reality, and another that views reality as a constructive process embedded in sociocultural practices with the possibility of acting on and transforming reality within the context of those practices.

With this background in hand, the next two sections detail some of the grounding assumptions that characterize our approach to constructivism, in order to better position the examples and recommendations to follow.

7.2 METAPHORS OF THE MIND

In 1980, George Lakoff and Mark Johnson published a book titled *Metaphors We Live By* (see also Lakoff, 1987; Johnson, 1987) in which they present a strong case that the way in which we perceive and think about a situation is a function of the metaphors we have adopted for and use in that situation. For example, Marshall (1988) has argued convincingly that the dominant metaphor in many schools is "School Is Work." We speak of students needing to *work* harder on their studies, to complete their home*work*, to earn a grade, and so forth. Teachers are trained to *manage* their classes and are often held *accountable* in terms of their *productivity*. These metaphors not only structure the way we think about schools, they also help create the world of the school. It is these metaphors, these grounding assumptions, that we want to examine.

To begin, we want to examine perhaps the most fundamental metaphor of all, our metaphor of mind. There have been many conceptions of mind throughout the history of philosophical and psychological inquiry (Gardner, 1985). Skipping lightly over several centuries of blank slates, wax tablets, telephone switchboards, and so forth, we want to summarize briefly two modern metaphors of mind before presenting our alternative.

7.2.1 Mind as Computer

First is the notion of "mind as computer" (MAC), the basic premise underlying early traditional artificial intelligence, but also much of instructional design and development. MAC assumes that the mind is an instantiation of a Turing machine, a symbol manipulation device (e.g., Newell & Simon: *General Problem Solver,* 1972). In this view, every cognitive process is algorithmic in the same sense that computer processes are algorithmic; i.e., the mind works by processing symbols according to rules. These symbols are entirely abstract and independent of any given individual's experience of them; i.e., the operation of the mind is completely independent of the person in whom it is contained. Meaning is mapped onto these symbols via our experiences in the world. Our understanding of the world is formed from a process of discovering reality "out there," interacting with it, and transferring that understanding into the mind, forming internal representations that determine our subsequent interactions with the environment. Symbols (or concepts) derive their meaning from their capacity to match (to a greater or lesser extent) aspects of reality. Any individual's internal representation will certainly depart from reality, but it does seem necessary to assume that, in principle, there must exist a conceptual framework that is entirely general and neutral, a single correct, completely objective way of representing the world. Learning is a process of information acquisition, processing according to innate or acquired rules, and storage for future use.

7.2.2 Mind as Brain

More recently cognitive scientists have proposed a metaphor of "mind as brain" (MAB), a view variously called *connectionism* or *parallel distributed processing* (see, for example, Rumelhart & McClelland, 1986). Connectionist models assume that symbols are learned consequences of particular experiences or interactions in the world, which are then mapped on or distributed across neural-like networks. Connectionism seeks to avoid the limitations of the MAC view and capitalize on precisely the experiential character of human concepts. It also deliberately links with our emergent knowledge of brain function; e.g., the brain would have to do massively parallel processing to accomplish even the most ordinary cognitive act, let alone the serial operations proposed by MAC models. Connectionism is the notion that intelligence emerges from the interactions of large numbers of simple processing units. Representations are not localized in some general-purpose symbol; rather they are distributed throughout a network of simple processing units according to patterns of activation that have emerged as a result of experience. Unlike MAC models, knowledge is not stored as a static copy of a pattern in long-term memory, with no real difference between what is retrieved and stored in working memory. Representation is an active process. What is stored in connectionist models are connection strengths between units that allow these patterns to be recreated (reconstructed). Consequently, learning is

> a matter of finding the right connection strengths so that the right pattern of activation will be produced under the right circumstances . . . , as a result of tuning of connections to capture the interdependencies between activations that the network is exposed to in the course of processing" (Rumelhart & McClelland, 1986, p. 32).

MAC and MAB models are alike in that both characterize mind as separate from the environment and as information processing bound within individuals. A major difference is that knowledge is a matter of storage and retrieval according to rules in the MAC view, but a function of distributed connection strengths and network activation for the MAB position. It is this difference that sets the stage for the possibility of some fresh thinking about the teaching/learning process.

7.2.3 Mind as Rhizome

The alternative we wish to propose here builds on the MAB metaphor but moves the mind out of the head and deliberately blurs or obliterates such common distinctions as environment/individual, inside/outside, and self/other. We will label our view "mind as rhizome" (MAR), a metaphor inspired by Umberto Eco (1984, p. 81; see also Deleuze & Guattari, 1983). A rhizome is a root crop, a prostrate or underground system of stems, roots, and fibers whose fruits are tubers, bulbs, and leaves. A tulip is a rhizome as is rice grass, even the familiar crab grass. The metaphor of rhizome specifically rejects the inevitability of such notions as hierarchy, order, node, kernel, or structure. The tangle of roots and tubers characteristic of rhizomes is meant to suggest a form of mind where:

- Every point can and must be connected with every other point, raising the possibility of an infinite juxtaposition.
- There are no fixed points or positions, only connections (relationships).
- The structure is dynamic, constantly changing, such that if a portion of the rhizome is broken off at any point it could be reconnected at another point, leaving the original potential for juxtaposition in place.
- There is no hierarchy or genealogy contained as where some points are inevitably superordinate or prior to others.
- The rhizome whole has no outside or inside but is rather an open network that can be connected with something else in all of its dimensions.

The notion of a rhizome is a difficult one to imagine, and any attempt to view it as a static picture risks minimizing its dynamic, temporal, and even self-contradictory character. Eco (1984) has labeled the rhizome as "an inconceivable globality" to highlight the impossibility of any global, overall description of the network. Since no one (user, scientist, or philosopher) can describe the whole, we are left with "local" descriptions, a vision of one or a few of the many potential structures derivable from the rhizome. Every local description of the network is an hypothesis, an abduction (see Shank, 1987) constantly subject to falsification. To quote Eco:

> Such a notion . . . does not deny the existence of structured knowledge; it only suggests that such a knowledge cannot be recognized and organized as a global system; it provides only "local" and transitory systems of knowledge which can be contradicted by alternative and equally "local" cultural organizations; every attempt to recognize these local organizations as unique and "global"—ignoring their partiality—produces an *ideological* bias (1984, p. 84).

This last statement emphasizes the point that we are not proposing the metaphor of rhizome for an individual mind, but to *minds* as distributed in social, cultural, historical, and institutional contexts. Except as a degenerate case, there is no such thing as a single mind, unconnected to other minds or to their (collective) social-cultural constructions. Thinking, or whatever we choose to call the activity of mind, is always dialogic, connected to another, either directly as in some communicative action or indirectly via some form of semiotic mediation: signs and/or tools appropriated from the sociocultural context.

Wertsch (1991), drawing inspiration from Vygotsky and Bakhtin, has argued this case very well (without invoking the metaphor of the rhizome), and we will present his view more fully. For our purposes here, we want to stress the potential connectivity implied by the MAR metaphor. We are connected to other people individually but also collectively, as in the speech communities or social languages in which we are all embedded. We are connected to the sociocultural milieu in which we operate, a milieu characterized by the tools (computers, cars, television, and so forth) and signs (language, mathematics, drawing, etc.), which we may appropriate for our thinking. Thus thinking is not an action that takes place within a mind within a body, but rather at the connections, in the interactions. But it is worth saying again that this thinking is always "local," always a limited subset of the potential (unlimited) rhizomous connections.

Learning, then, is neither a matter of discriminating the symbols of the world and the rules for manipulating them nor of activating the right connections in the brain. It is, rather, a matter of constructing and navigating a local, situated path through a rhizomous labyrinth, a process of dialogue and negotiation with and within a local sociocultural context. Although this analogy fails if pushed too far, the connectivity we have in mind is a bit like the World Wide Web (WWW). While the "results" of a connection to WWW is experienced via an interface with one's local workstation, that experience is possible only as a result of connections with many (potentially an infinite number of) servers all over the world. The local workstation both contributes to (constructs) and is constructed by its connections.

7.3 METAPHORS WE TEACH BY

Given this background, we are now in a position to present and justify some of the grounding assumptions of our version of constructivism. We have separately (e.g., Cunningham, Knight & Watson, 1994; Savery & Duffy, 1995; Duffy, 1995) and jointly (Cunningham, Duffy & Knuth, 1992) offered such assumptions before, but never within the context of a model of "mind as rhizome." This addition has helped clarify our own thinking and, we hope, the readers'.

7.3.1 All Knowledge Is Constructed; All Learning Is a Process of Construction

In accord with the MAR metaphor, all knowledge is local, a slice through the rhizome. Since all connections are, in principle, possible, we must stress that we are not talking about a partial or incomplete version of the "truth," the world as it is unmediated by sensation, perception, or cognition. Elsewhere we have talked about the concept of *umwelt* (Cunningham, 1992), a term coined by Jacob von Uexkull (1957) and discussed in his brilliant paper "A Stroll Through the Worlds of Animals and Men." In brief, the term means phenomenal world or self-world, the worlds that organisms individually and collectively create and that then serve to mediate their experience in the world. It is these structures that determine a world view, the things we notice and ignore, the things that are important to us and not important, the means by which we organize our lives. This umwelt, determined jointly by species-specific factors, the sociocultural history of the community, and particular experiences of the organism in a given environment, characterizes that organism's behavior.[5]

In humans, this process of construction (or *semiosis*, as we prefer to call it) is unique in the universe as we know it. Structures are created which go beyond the immediate experience of the cognisizing organism. Words, pictures, mathematics, bodily movements, and the like generate structures of knowledge and objects that need have no basis in the "real" world and which can be manipulated independent of any such world. According to Deely (1982), it is the intervention of language that allows humans to engage in this particular type of semiosis. Through language, we create culture: institutions such as religions, governments, armies, schools, marriage rites, science, and so forth. Culture, in turn, impacts our lives by determining what is important and what is not, what makes sense and what does not. The culture then makes these constructions available to the young and to new initiates for appropriation and use in transforming their participation in that culture.

Learning, then, becomes a matter of changes in one's relation to the culture(s) to which one is connected—with the gradual transformation of one's means of constructing one's world as a function of the change in membership in that culture. Lave and Wenger (1991) discuss this in terms of legitimate peripheral participation: a transformation from newcomer to old timer. These cultures can be conceived at various levels (e.g., caregiver, family, school, church, ethnic community, vocation, nationality, etc.), activities (working, playing, talking, eating, etc.), tools (hammers, computers, televisions, cars, etc.) and signs (language, music, art, etc.). A complete explication of such a view goes well beyond our purposes for this chapter, but it is necessary to stress again the constructedness of our knowledge and the need to provide experience to learners of that constructedness and the means by which they can participate in that process. This will be detailed in the sections to follow.

7.3.2 Many World Views Can Be Constructed; Hence There Will Be Multiple Perspectives

We and other constructivists are often accused of advocating a kind of naive relativism or constructivist extremism. Since we argue that all knowledge is constructed, it is assumed that we must therefore accept the claim that every individual constructs his or her own meaning, untroubled by the realities of the real world or contact with other individuals. For example, Schwen, Goodrum, and Dorsey (1993) propound that they "find the extreme view of all knowledge being relevant to personal experience, and therefore idiosyncratic, too impractical and anarchic to be useful" (p. 6). But such a fundamental misconstrual of our position precisely illustrates our second principle and is nicely captured by Eco (1984, p. 12): "A world view can conceive of anything except an alternative world view."

As the MAR metaphor makes clear, knowledge is a construction, not by an individual in some pristine, autistic isolation but by participants in a community that simultaneously transforms and is transformed by such participation. What we choose to call *knowledge* is a consensus of beliefs, a consensus open to continual negotiation (Rorty, 1991). Such a process does not mean that the community will inevitably and perpetually debate whether the sea is blue or green, whether the word *dog* will continue to refer to a four-legged, domesticated, carnivorous canine, whether the Earth orbits the sun, or whether God is dead. A pervasive and largely benign effect of the structure of knowledge that we construct from the rhizome is that we tend to use those structures through which the world makes good sense to us, that seem "right." And we tend to assume that others see things in roughly the same way we do, that our world view is constructed as largely invisible. Providing experience that elevates our world view to a conscious level typically entails bringing up alternative views for comparison, as when we study cultures different from our own.

[5]It is important to distinguish the concept of umwelt from the more familiar concept of environment, for it is here where differences between MAR and other views are most striking. An environment is a physical setting that impacts the organism and serves as a source of stimulation. As such, it can be conceived independently of the organism in question and in fact is usually spoken of as an entity that exists for a multitude of different organisms. This separation of organism and environment is a fundamental tenet of most method and theory in instructional psychology, in particular, and psychology, in general. The umwelt of an organism, however, is not independent of the organism; in fact, it exists only in relation to the organism. In a famous example, von Uexkull (1957) described the various umwelten created by a tree: a rough-textured and convoluted terrain for a bug, a menacing form for a young child, a set of limbs for a nesting bird, and so on. In all these cases, the environment of the tree was the same; that is, the bark, the height, the limbs were "available" to each of the organisms, yet their experience of them was quite different.

In a classroom with which we have worked (Cunningham, 1994), the teacher is exchanging material (stories, letters, photographs, HyperCard stacks, etc.) with a similar classroom in Northern Ireland. The children in both cultures are constantly surprised by the differences that have been revealed, from simple things like the way a date is written or the likelihood that the family owns a car, to the extreme, as when the children in Northern Ireland talk about the "Troubles" (the sectarian violence). The children in both cultures are invited to put themselves in the perspective of the other and examine their own cultural practices based on this new perspective. What would it be like to live in a town where army patrols can be seen several times a day? To come upon a policeman with a cocked semiautomatic weapon? On the other hand, what is it like to live in a culture where person-on-person crime is common (such crimes are rare in Northern Ireland in comparison to the U.S.)? Even a term like *integrated school* has fundamentally different meanings in the two communities.

The "reality" of multiple perspectives should be a cause for celebration and optimism, not for fear that we will sink into some kind of utter subjectivism. Those who hold MAC view of mind expect and encourage acceptance and closure of a world view, while the MAB and MAR metaphors anticipate and encourage debate. It is this engagement with others, this establishment of the need to continually expand our web of understanding, that creates the awareness of multiple perspectives.

7.3.3 Knowledge Is Context Dependent, So Learning Should Occur in Contexts to Which It Is Relevant

Speaking of debate, this is a principle about which the authors have debated long and enthusiastically. While we are in sympathy with views of our colleagues concerning the need to situate (e.g., Brown, Collins & Duguid, 1989) or anchor (CTGV, 1992) learning in authentic, relevant, and/or realistic contexts, we disagree about why this is important. One of us (DJC) draws inspiration from the systems theoretic view of Maturana and Varela (1992), who argue that to say that someone *knows* something is to make the claim that she is acting effectively in a particular context. Thus to claim that Stephen W. Hawking knows science is to assert as valid that he behaves effectively in the domains of action that are accepted by the scientific community, a community that he in fact helps create. Knowledge is effective action. The contexts within which one can act effectively is an empirical matter. (See also Lave & Wenger, 1991.)

It is on the point of that empirical matter and its practical implications that the authors part company. The other author (TMD) agrees that to know something means that the individual can act effectively in a particular context. The concern is not with knowledge but with learning and, perhaps most importantly, with the issue of transfer. That is, if I want to prepare myself to be a scientist, what sort of learning activity must I engage in and in what sort of environment? It would seem that the general statement of this question—i.e., how do we prepare ourselves to act effectively in particular contexts?—is central to our development as individuals and as a society. It is certainly central to the instructional design community.

Thus the question of context is really a question about what aspects of the context must be represented if the learning (knowledge) is to be used (elicited?) in other contexts. TMD discusses this issue at length elsewhere (Honebein, Duffy & Fishman, 1993). In brief, the focus is on the qualitative character of the metacognitive and cognitive processing and the skills required. The physical character of the environment is relevant only to the extent it impacts the character of the "thinking" and skill requirements.

This entire issue of learning and transfer raises a problem for both authors and for most constructivist theory. It has been labeled the "learning paradox" by Fodor (1980) and Bereiter (1985). The MAR view, and more generally the sociocultural constructivist's view, stresses the distribution of cognition in the environment. While Vygotsky discusses the internalization of social experience (with the implication that knowledge is internalized and hence stored), more recent sociocultural theorists have suggested that a better translation of the original Russian is "appropriation" rather than "internalization" (Rogoff, 1990). In this way, the concept of distributed cognition (the rhizome distributed across minds and cultural artifacts) would seem to be preserved. However, as Ann Brown, Ash, Rutherford, etc. (1993) have noted, this shift in terminology does not resolve the learning paradox.

We certainly do not have the solution to the learning paradox, and our own debate will continue. DJC worries that a view that posits abstract, generalizable operations, divorced from the contexts within which they were developed, will lead back to a MAC metaphor, while TMD worries that the focus on knowing fails to help us move forward on the critical issues of learning and the design of learning environments. Stay tuned.

7.3.4 Learning Is Mediated by Tools and Signs

In many ways, this assumption lies at the heart of constructivism as we view it. Wertsch (1994) agrees, asserting that any adequate theory of higher mental processes (i.e., beyond perception and involuntary attention) must be grounded in the notion of mediated action. Vygotsky (1978, p. 57) has argued that children's development proceeds on the basis of appropriating mediational means from the sociocultural milieu: "Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first, between people, then inside the child. . . . All the higher functions originate as actual relations between individuals." Vygotsky has proposed two mediational means: tools (technical tools) and signs (semiotic tools). The distinction is a slippery one, and particular examples often move back and forth between (even straddle) the two categories. But consider a hammer as a prototype example of a technical tool. How does the appropriation of this tool from the sociocultural milieu mediate action? As the needs of the culture encouraged the invention of a hammer as a more efficient means of driving posts into the ground or joining two boards, the hammer itself altered the very nature of carpentry itself. While it is true that the goal of driving a nail into a board is mediated by the use of a hammer, the invention of the hammer has radically altered the character of the structures we build (e.g., shelters built without the aid of a hammer tend to be less angular). Thus the invention of a tool and its use by members doesn't simply facilitate forms of action that would occur anyway; the tool changes the form, structure, and character of the activity.

If this is true for hammers, consider how substantial is the influence of more modern technological tools like automobiles, computers, video, etc. (see 20.4 for other examples). The word processor on which we write hasn't merely helped us to be more efficient in our professional writing as we did it 25 years ago. The nature of that writing process has changed radically. Culture creates the tool, but the tool changes the culture. Participants in the culture appropriate these tools from their culture to meet their goals and thereby transform their participation in the culture.

The computer is a good example of a mediational means that has aspects of both tool and sign. During the time and place where Vygotsky was writing, tools were used almost exclusively for physical labor, to manipulate physical objects in the environment. Signs, on the other hand, are mediational means used for cognitive functioning, and certainly word processors influence the writer as well as the written product. Language, of course, was the semiotic means about which Vygotsky wrote the most, but he also included numbers, algebraic notation, mnemonic techniques (his famous knot in a string to remember something), diagrams, maps, musical notation, etc. In fact these means are very reminiscent of the multiple intelligences proposed by Howard Gardner (e.g., 1993): linguistic, musical, logical-mathematical, spatial, bodily-kinesthetic, interpersonal and intrapersonal.[6] All these are not simply alternative means of expressing some underlying meaning but rather semiautonomous systems for constructing meaning. They too have been invented by culture to address some need of the culture, but by their use actively transform the culture. It is the action produced by these mediational means that is crucial. Thus, humans "play an active role in using and transforming cultural tools and their associated meaning system." (Wertsch, 1994, p. 204). Wertsch goes on to argue that the "essence of mediated action is that it involves a kind of tension between the mediational means as provided in the sociocultural setting, and the unique contextualized use of these means in carrying out particular, concrete actions" (Wertsch, 1994, p. 205). In other words, all distinctly human instances of learning are constructions situated within a context that employs some form of mediational means, tools, and/or signs.

7.3.5 Learning Is an Inherently Social-Dialogical Activity

This assumption is actually a part of the previous one, but since Vygotsky and his followers have emphasized language as a mediational means above all others,[7] we felt it warranted separate treatment. Certainly the central position of language and dialogue in human culture and cognition can hardly be overemphasized.

In many educational applications commonly characterized as constructivist (e.g., reciprocal teaching, problem-based learning, collaborative groups, etc.), one finds a strong emphasis on dyadic or group discussion: talk, talk, talk! Even in applications like hypermedia systems that are intended for single users, the interface often models a dialogic structure, as in querying a database to solve a problem (Knuth, 1992), or actually includes means for synchronous or asynchronous dialogue among users (Duffy, 1995; Duffy & Knuth, 1990). Why this emphasis on dialogue?

A child is born into a sociocultural milieu that functions on the basis of some socially organized processes: operations, objects, and structures. As the child acts in this context, she is exposed to these means by which the community mediates its activities. Caregivers use language to interact with the child and intuitively coordinate these linguistic actions with the child's behavior. The child then appropriates this language tool to further influence and control her social interactions, but by adopting this mediational sign has transformed her ability to influence her *own* actions within her developing spheres of action. According to Wertsch: "The incorporation of mediational means does not simply facilitate action that could have occurred without them; instead, as Vygotsky (1981) noted, 'by being included in the process of behavior, the psychological tool alters the entire flow and structure of mental functions' " (1991, p. 137).

[6] While we are attracted by Gardner's view of multiple semiotic systems, we are not enamored with his view of education as the assessment of intellectual ability and the matching of instruction to the ability pattern of the student (Gardner, 1993, pp. 10–11). This seems to us to compound the error of assuming that one or two scores on an intelligence test can define the appropriate instruction for a child. One, two, seven, or a hundred, the error is in assuming that a score on a decontextualized task has relevance to learning out of the school context. We prefer Charles Morris's (1946) exhortation: "Training in the flexible use of signs means gaining the ability to enter into fruitful interaction with persons whose signs differ from one's own, 'translating' their signs into one's own vocabulary and one's own signs into their vocabulary, adapting discourse to the unique problems of diverse individuals interacting in unique situations" (p. 246).

[7] Wertsch (1991) speculates that Vygotsky's own cultural background (he grew up in a Jewish-Russian family with considerable intellectual stimulation) and the grounding of much of his work in the formal instruction of literacy accounts for this emphasis.

A primary way in which mental functions are altered by the mediation of language signs is that knowledge, and thereby learning, becomes a social, communicative, and discursive process, inexorably grounded in talk. James Wertsch (1991) has been particularly influential in arguing this case by presenting the views of a contemporary of Vygotsky, M. M. Bakhtin. Bakhtin focused his analysis on the utterance, or the shared activity of speech communication—that is, voice. In other words, he stresses the social functions of the linguistic sign, its use as a mediational means to express and share meanings within a social language community. Bakhtin has coined a wonderful term, *ventriloquation*, which is the process by means of which one individual (or voice) speaks through the voices or the language of a social community. In a very real sense, the way in which a student comes to manifest the effective behavior of a community (e.g., the community of scientists) is to speak with the voice of that community (e.g., to talk like a scientist). Paulo Freire's (1993) work has also stressed the importance of voice and dialogue as a means for action within a sociocultural context.

7.3.6 Learners Are Distributed, Multidimensional Participants in a Sociocultural Process

Perhaps the most "revolutionary" aspect of the MAR metaphor is the concept of a distributed mind and its corollary, a distributed self. Displacing the individual from the central position in cognitive action is, we suspect, a shift on a par with displacing the earth from the center of the universe. And yet more and more books and articles with titles like *Socially Shared Cognition* (Resnick, Levine & Teasley, 1991), *Distributed Cognitions* (Salomon, 1993), and *Distributed Decision Making* (Rasmussen, Brehmer & Leplat, 1991) are appearing. Lave and Wenger (1991) use the term *whole person* to characterize this conception of self, where learning is not a matter of a person's internalizing knowledge but a matter of a person's transforming his participation in a social community. The whole person defines as well as is defined by this participation. Lave and Wenger (1991, p. 53) describe identities as "long-term, living relations between persons and their place and participation in communities of practice."

Hutchins (1991) proposes a simple thought experiment to illustrate this idea. Look around where you are right now reading this and try to find something that "was not either produced or delivered to its present location by the cooperative efforts of humans working in socially organized groups" (p. 284). Unless your environment is strikingly different from ours, we think you will have difficulty identifying anything. Of course, your inclination is to declare those objects as different from you, as something other than self, but are they not really part and parcel of the means by which you participate in the communities that produced them? Isn't that your identity?

We won't belabor the point, but it should be clear that a distributed concept of self shifts the activity of learning to the connections one has with communities, to the patterns of participation, and away from efficient internalization of knowledge. Here then is another reason why so many constructivist applications employ discussion and dialogue in groups. Learning is not the lonely act of an individual, even when it is undertaken alone. It is a matter of being initiated into the practices of a community, of moving from legitimate peripheral participation to centripetal participation in the actions of a learning community (Lave & Wenger, 1991).

In anticipation of a common criticism, we would like to stress that the notion of distributed self does not remove self-agency from the learning process. It is sometimes argued that in models like this, the needs of the individual are sacrificed to the demands of the community. We admit that this is a danger, but no more so than the danger of indoctrination inherent in the process of internalization of knowledge transmitted from teacher or lesson to the learner. The important element missing in our model thus far, that of reflexivity, will reinforce the importance of self-agency (see 7.3.7).

7.3.7 Knowing How We Know Is the Ultimate Human Accomplishment

This last principle is the most important and probably the least controversial. We can't think of a single model of the teaching/learning process that would not stress the importance of self-awareness of learning and knowing. Certainly the extensive literature on metacognition (e.g., Flavell, 1979), thinking skills (e.g., Baron & Sternberg, 1987), theory of mind (e.g., Wellman, 1990), etc., within cognitive psychology are all pointed to the development of self-monitoring and self-control of the learning process. Even Skinner (1968, pp. 172–73) encourages learners to analyze the contingencies (see 2.2.1.3.1) that control their behavior and deliberately manipulate them so as to become self-reliant and self-managing (he even uses the word *freedom* to characterize this process!).

Where we differ, of course, is our account of the teaching/learning processes of which one should be aware! Many models of metacognition stress the development of strategies of efficient processing: primarily storage and retrieval (e.g., Bornstein, 1979). Programs in thinking skills frequently focus on the problem-solving process and train students to use systematic analytical procedures like Bransford and Stein's (1984) IDEAL problem solver or Sternberg's (1987) metacomponents. While we are unaware of any particular applications derived specifically from the MAB metaphor, we suspect that they would emphasize the process of perceptual tuning, perhaps in the sense of Donald Schon's (1987) reflective practitioner developing the ability to "see as."

We prefer the term *reflexivity*, which means directed, or turned back upon itself, or self-referential. To be reflexive about the principles cited above is to direct them back on your own efforts to learn, teach, and know. As specified in the principles above, we regard all learning as a social, dialogical process of construction by distributed, multidimensional selves using tools and signs within contexts created by the various communities with which they interact. This, we believe, is an entirely natural process of which we are ordinarily no more aware than we are of breathing or of our heartbeat. Our process of construction is directed toward creating a world that makes sense to us, one that is adequate for our everyday functioning. We are generally unaware of the beliefs we have adopted or created to live and teach by, but raising them to awareness can have salutary effects. Umberto Eco put the matter this way:

> To speak about "speaking," to signify signification, or to communicate about communication cannot but influence the universe of speaking, signifying, and communicating (1976, p. 29).

How do beliefs change? How do we become aware of them? When we are confronted with some experience not accounted for by our existing beliefs, we invent a new set of beliefs or revise an existing one, a process we have elsewhere referred to as *abduction* (Cunningham, 1992). This new structure will provide a context within which the surprising experience is a matter of course (i.e., it makes sense). Abduction is instigated when we are in a condition of inadequacy or uncertainty that arises from experience; hence it is naturally embedded in a relevant context (is situated or anchored). Thus when we experience or are shown a situation where our existing beliefs are inadequate, our awareness of our own state of knowing is enhanced. This is the essence of reflexivity.

Further awareness of the cultural origin and mediated nature of our beliefs allows us to explore varieties of belief structures. A reflexive analysis of the metaphors by which we live and teach will allow us to reconsider them. If we are not satisfied with the metaphor of "school is work," let's try another: "school as consulting service." Under this model, the school might be seen as a community resource where the teachers, students, equipment, and facilities are placed at the service of members of the community who may bring problems and issues to be addressed. Teachers and more experienced students mentor the younger ones during problem-solving projects geared toward the betterment of the community of which all are a part. But if this metaphor proves unuseful, try another!

Finally, we believe that via reflexivity, and in a manner not possible in other models, learners have real control over and responsibility for their beliefs. An awareness of the principles of constructivism listed above demands a strong sense of responsibility for the state of the world in which we find ourselves. If many world views are possible, then our choice of participation in the community that holds a particular view requires both a commitment to and a responsibility to respect the views of others. We have within our capability the constant renewal of our world view. Human reflection is the key to understanding and creating anew a world in which we coexist with others. Someone else's world view, her belief structure, can be as legitimate as our own. To coexist, a broader perspective is necessary, one in which both parties cooperate to bring forth a common world where many perspectives are valid.

7.4 REEXAMINING SOME KEY CONCEPTS

In this section we would like to review some of the key concepts in instructional design and instructional methods, examining them from our constructivist perspective. In this discussion, it should be clear that methods can be implemented in many different ways, and how a method is implemented and what is the focus in that implementation is reflective of one's views of learning.

7.4.1 Discovery Learning

Discovery learning has a long and complex history in education (see Dewey, 1929; Bruner, 1961; Page, 1990). While it reached its heyday as a pedagogical framework in the 1960s, the generality of the term allows it to be applied to any learning environment in which the student is actively involved in problem solving (Bruner, 1961).

Discovery learning in its original formulation focused on the learning process, the goal being to develop inquiry skills in a content domain, an appreciation of inquiry as a way of approaching issues, and an appreciation of the complex issues in a domain. This view of defining what is learned in terms of the interrelationship of process and content is perhaps best exemplified in Bruner's design of the social studies curriculum, MACOS (Bruner, 1966; Bruner & Dow, undated). However, in its implementation over the years, in the form of the "new math," "open classroom," and other movements, discovery learning was employed as a method for acquiring content. The content goals remained the same as for other learning environments—knowledge was still seen as an entity—but the strategy for acquisition changed to one of "discovery."

The consequence of this view of discovery is that the students' inquiry is not honored. Rather, the learner has to discover the answer that the teacher already knows. Needless to say, learners quickly discover that the goal is not inquiry or exploration of a domain but rather discovering what the teacher wants them to discover. Rather than learner centered, the instruction is quite clearly teacher centered.

This view of discovery is perhaps an unfortunate consequence of the metaphor; "to discover" suggests that there is something (knowledge) hidden away, and our job is to find and acquire it. An alternative view of discovery is to think of it in terms of "invention," a personal construction, rather than as a discovery of what exists. From this perspective, we take as the goal of instruction not the acquisition of a specific, well-defined bit of content but rather the ability to learn in a content domain. Learning to learn—including the ability to ask questions, evaluate one's strategies, and develop answers to questions in the content domain—is the goal in this view of discovery learning (Brown et al., 1993). Such a goal requires a unity of process and content; both are integral and inseparable in developing the ability to work and think in the content domain. In this learning-to-learn view of discovery learning, the knowledge is in the learner's activity rather than being in the text. Thus it is a view that is fully consistent with the constructivist viewpoints.

In summary, if the goal is simply to learn a well-defined content—definition and procedures—then a discovery approach is not necessary. The learner should simply be told the answers and either given a memory (job) aid or required to memorize it. However, if the goal is to be able to use the information in a content domain, to be able to think in the content domain, to be able to invent defensible understandings, then the discovery method is appropriate.

7.4.2 Zone of Proximal Development

Vygotsky (1978, p. 86) defines the zone of proximal development (Zo-ped) as "the distance between the actual developmental level of a child as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers." In other words, we are describing a form of "joint" cognition, where the tutor provides support or scaffolding for the individual until the individual appropriates the knowledge or skill and brings it under his conscious control for his own use. The support is progressively withdrawn and, as the students take over more and more responsibility in a problem-solving situation, they become self-regulated and independent.

We would broaden the focus in two interrelated ways. First, there is a matter of perspective. Rather than talking about what we do to an individual, we would prefer to discuss the affordances of the environment. Thus, we can look more broadly at the environment to determine how the environment is designed to be supportive of the individual in relation to accomplishing some task. Neither the student nor the teacher "owns" the Zo-ped; rather, it is something that is established dynamically. From an instructional design perspective, this shifts the focus from what we teach to how we design a learning environment that will support the learner as he or she may request support, and can be discarded by that learner when it is no longer required.

Second, our broader view of the Zo-ped looks at the full cultural context of the individual's learning environment. Cole (1985) has characterized the Zo-ped as "where culture and cognition create each other." We can think of the Zo-ped in terms of what an individual can do as a function of being a part of a specific culture that would not be possible if he or she were not a part of that culture, and, as Cole's remark suggests, the changes in the individual, in turn, change the culture. Thus the full sociohistorical context is a part of the Zo-ped for development. An implication of this is that we can look at what a Zo-ped affords in any cultural context by simply looking at the difference between newcomers and old-timers in that community (Lave & Wenger, 1991).

This view has interesting implications for the distinction between learning and instruction (see, e.g., Heinich, Molenda & Russell, 1993) where instruction is defined as particular context for learning in which we purposefully organize the environment to achieve particular learning objectives. In the view we are discussing, there are a wide range of social situations that are designed to promote learning of particular goals. In our view, these social contexts are instructional environments. They differ from what we normally describe as instruction simply because we typically conceive of instruction as the formalized delivery or transmission of information. However, there are designed formal and informal social structures that teach the newcomer the rules and procedures of conduct. For example, Lave and Wenger (1991) describe the design of AA meetings such that individuals stand up and share stories. They provide a very nice analysis of this "instructional strategy" and its impact on newcomers. More generally, we could examine any community and look at the structure of the community as well as the effect that structure has on how we learn to behave. Some instructional designers might want to argue that such an environment is not designed, and hence it is not instructional. However, we would argue very strongly that it is designed to achieve particular ends. Simply try to change the structure of the community (the tacit rules) and see how the members would react. And of course, anyone who fails to learn is redirected in a manner analogous to any training program.

7.4.3 Scaffolding

Success in the Zo-ped requires support for learning, and that support is called the *scaffolding*. Indeed, the Zo-ped is defined in terms of the scaffolding or affordances of the environment. Scaffolding includes the support of other individuals, any artifacts in the environment that afford support, as well as the cultural context and history the individuals bring to the Zo-ped. We will discuss the role of the teacher in greater detail in the next two sections. At this point, we simply wish to clarify the general notion of the power relationship within the Zo-ped.

The scaffolding metaphor implies a rigid structure that is used to construct. That is, the placing of the scaffold presupposes much of the character of the structure being built. In our mind, this is an unfortunate choice of metaphors since it suggests a guiding and teaching of the learner toward some well-defined (structural) end. This "structural" metaphor of a scaffold is consistent with the objectivist view of instruction in which the teacher arranges the environment (including the teaching activities) to help the learner acquire the prespecified "knowledge." This view of scaffolding presents the Zo-ped as a teaching environment rather than as a learning environment. It is a model of transmission, the "objects" that provide the support/scaffold form the individual.

From our perspective, the Zo-ped and the scaffolding must be viewed as a learning environment—as supporting the growth of the learner. Griffin and Cole provide what we feel is an excellent contrast of the learning vs. teaching concept of scaffolding in the Zo-ped: "a Zo-ped is a dialogue between the child and his future; it is not a dialogue between the child and the adult's past" (1984, p. 62).

7.4.4 Cognitive Apprenticeship

The influential papers of Resnick (1987) and Brown, Collins, and Duiguid (1989) led to a renewal of interest in apprenticeship as a design for learning environments. The focus, however, shifted from physical job skills to the development of cognitive skills. The result was a focus on authentic learning environments where the cognitive demands in the learning are qualitatively the same as the cognitive demands of the environment for which the instruction was preparatory.

We fully agree with the focus on authentic cognitive demands. Indeed, this is consistent with our emphasis that the learning is in the activity of the learner, and hence we must examine the activity and the full sociocultural context in which it occurs. In traditional instruction, the learner's cognitive activity is centered on the development of strategies for determining what the text and the teacher are signaling as important, processing and remembering the information, and for evaluating test items to determine correct answers. These are all skills preparatory for more schooling—it is a cognitive apprenticeship for schooling—but not for much else (Honebein, Duffy & Fishman, 1993). Engaging learners in cognitive and metacognitive activities that involve the authentic use of information is a central goal in our instructional design.

While we agree with the focus on authentic cognitive activity, there are other aspects in the development of the concept of cognitive apprenticeship with which we are less sanguine. Our primary concern is that there has been a focus on cognitive apprenticeship as a "master-apprentice" relationship with an implicit view that the core of the apprenticeship is the master teaching the apprentice. Indeed, the most often-cited examples of cognitive apprenticeship are reciprocal teaching (Palinscar & Brown, 1984) and modeling "thinking like a mathematician" (Schoenfeld, 1991), both of which focus almost exclusively on a knowledgeable master working with the less-knowledgeable learner. This model of cognitive apprenticeship is more in line with the MAB or even with the MAC models of mind. It focuses on the individual cognitive activity (Kang, 1995).

Lave and Wenger (1991) present a view of cognitive apprenticeship more in line with our MAR model of mind. Rather than the master-apprentice relationship being central, Lave and Wenger examine the full sociocultural context of which the individual is a part. They discuss apprenticeship as being a legitimate peripheral participant in a social context. By this they mean that the individual is legitimately a participant but is only playing a partial role in the context. There is not a master who assigns tasks or who monitors the apprentice's behavior. Rather, the apprentice begins to assume responsibilities, testing his or her ability to assume roles and responsibilities in that environment. The full cultural context—the artifacts as well as the experts (or old-timers)—afford the learner support (scaffold) as the learner attempts to take on these responsibilities. Lave and Wenger note that in most apprentice environments there is little direct teaching between master and apprentice.

In addition to decentering the "master" in the apprenticeship environment, Lave and Wenger argue that it is not so much that apprenticeship is the "best" learning environment; it is simply that it is a prevalent learning environment. In addition to formal apprenticeship, most informal learning can be interpreted from the perspective of "apprenticing" (see 20.3.1). In most new contexts, we first observe and then begin to take on some responsibilities in a group we wish to become an integral part of. Lave and Wenger provide several excellent examples of both formal and informal apprenticeships as a means to illustrate their concept of legitimate peripheral participation and to begin to analyze some of the critical variables in successful apprenticeships.

In summary, from an instructional design perspective, the apprentice environment is one way to view the design of a learning environment. However, in doing so the emphasis is not on master-apprentice but rather on the learner as a member of a larger community of practice who, through legitimate peripheral participation and the affordances of the environment, begins to assume greater responsibility in that community of practice. Thus our design must provide the learner access to that community of practice and provide the tools that will support the learner in assuming his or her role in that practice. The instructional principles outlined in the previous section provide the guidance in designing such an environment.

7.4.5 Coaching

We no longer teach, but rather we coach—we have moved from the sage on the stage to the guide on the side. The coach provides the scaffold for the learner. This is becoming common rhetoric in instructional theory, and the constructivist "movement" has been a primary stimulus for this shift in the teacher/trainer role. It is not so much that the teacher is seen as less important, rather the role of the teacher changes so that the focus is on aiding or providing the scaffolding for the learners rather than telling the learner. We fully appreciate this goal of decentering the teacher as the fount of knowledge. However, our concern is that the shift is a shift in method rather than a shift in the conceptual framework underlying the method—a trivial rather than a radical constructivist shift in von Glasersfeld's (1989) terms.

By a shift in method, we mean that while the method has moved from sage on the stage to guide on the side, the guide is still the fount of knowledge. He or she still possesses the knowledge the student is to acquire. It is a unidirectional relationship in which the student observes and mimics or follows the instructions of the coach. The coach, in turn, models the behavior or provides the answers. We coach the learner by giving the learner our knowledge, which is to be replicated. This is in large part consistent with the cognitive apprentice model advocated by Brown et al. (1989). Of course, this view is not much different from the traditional view of learning. Knowledge is still this entity to be transmitted from coach to learner—a new instructional method, but the same view of learning and knowledge.

Within our MAR constructivist framework, the coach-learner relationship is bidirectional. The skills and knowledge of both coach and learner are attended to and honored. Fosnot (1989) describes this as a mentor-protégé relationship in which the mentor begins by seeking to understand and expand the learner's or protégé's current conceptions. Thus both mentor and protégé are seeking to understand the other's views. Rather than the end goal being that the learner can replicate the coach's behavior or follow the coach's directions, it is that the mentor and learner come to an agreement even if it is an agreement to disagree. That is, the learner may not mimic the coach, but the deviations are knowledgeable deviations that the learner can defend and the coach can respect.

We can see for ourselves, and hopefully illustrate for the reader, the implications of these two points of view in our interactions with students and, oftentimes, even in our interactions with each other as we discuss research and theory. The most "natural" approach to an issue-based discussion is to have generated one's own point of view, one's own answer to the question on the table. Then, in conversing (coaching) student or colleague, we listen to see how what they say matches our conceptualization, and we catalogue the matches and the mismatches. Our response, then, is a question or comment that helps the learner understand our different points of view and encourages them to accept the alternative. This is the coaching framework that calls for the learner or colleague to mimic our point of view.

The alternative framework—the mentoring approach—would have us listening to the student or colleague to understand his or her point of view. We would then ask questions to help us clarify those aspects that we did not understand. Only after we felt a reasonable understanding of that alternative view would we engage in a discussion to try to understand and perhaps resolve the differences. But it may well be that the alternatives are compatible and each is acceptable. Fosnot has offered the following prescription for coaching preservice teachers within the constructivist framework, a prescription that is a method reflective of the underlying theory. It should be noted that while it is similar to the Socratic method, the acknowledgment of defensible alternative perspectives provides the deviation from the mimic aspect of the Socratic method:

1. The mentor learns the protégé's point of view through careful listening and probing.
2. The mentor teaches by inquiring at the "leading edge" of the protégé's thinking and by attempting to facilitate disequilibrium.
3. The mentor constructs a line of inquiry meaningful to the protégé, and the protégé constructs a line of reasoning meaningful to the mentor.
4. The mentor acknowledges that the protégé has the intellectual freedom to adopt and modify the pedagogical orientation of his or her choice (Fosnot, 1989, p. 97).

7.4.6 Context

In instructional and educational research, we have traditionally viewed context as a variable in our research. Context can be decomposed into components, and those components can be manipulated. The context sits separate from the individual and can be manipulated independently of the individual. This is an objectivist view of context more fitting of the MAC model of mind (see footnote 4, p. 172).

The constructivist view of context we would argue for has the context as a dynamic whole, including the individual and the sociohistorical context. The mind as rhizome provides one metaphor for this view, where elements can be pointed to much as the tubers, but in the context of the whole we cannot identify, where one element leaves off and another begins. Birdwhistell offers an analogous metaphor to explain this view of context:

> . . . sometimes I like to think of a rope. The fibers that make up the rope are discontinuous; when you twist them together, you do not make them continuous, you make the thread continuous . . . even though it may look in a thread as though each of those particles are going all through it, that isn't the case . . . that's essentially the descriptive model (Birdwhistell as cited in McDermott, 1980).

7.4.7 Learner Control

Learner control is a concept that was introduced in relation to computer-based instruction (see 23.9). At issue is how much or what type of control should be given to the learner during the learning process? The alternatives are learner control, computer control, or shared control. What is it that is controlled? Basically the control decision has to do with the pacing of the information presented, the sequence of the information, and the actual content (Milheim & Martin, 1991).

This is perhaps the epitome of an objectivist view of learning. The content of instruction is almost totally divorced from learning activity except as it is related to "processing" variables for "inputting" information. Learning is the input and mastery of particular content, the ability to repeat it, apply it, discriminate it where "it" is well defined. The ability of the person to think in the domain—to evaluate his understanding, judge relevance, and make decisions of what he needs toward what end—is irrelevant. Indeed, the irrelevance of thinking to the learning activity is reflected in this summary statement of the general view of learner control in instructional design and the state of our research findings:

> The notion of learner control has long held *intuitive* appeal for developers of computer-assisted instruction, but

its apparent *potential for improving learning* has never been experimentally established" (emphasis added, Goforth, 1994, p. 1).

And what is the intuitive appeal? It would seem that the belief is that learners should know best what they need, and so learning will be more efficient if they are in control. It has nothing to do with the thinking process being an integral part of knowing. As Ross and Morrison (1989) note, the notion of giving the learners control of their learning activities is based on two assumptions: learners know what is best for them, and they are capable of acting appropriately on that knowledge. If the learner does not meet either of these assumptions, then control of "learning" is given to the computer so that learning can occur "efficiently."

The concept of learner control is similar to the concept of teacher-centered instruction in the noncomputer environment. That is, rather than supporting learners in developing control of their own learning and hence of being able to think in a domain, the teacher-centered and computer-controlled instructional approaches take responsibility away from the learner. However, in teacher control, it is primarily a control of the content and the basic learner task. In computer-control literature, the control is far more pervasive in that the computer takes over even the minute decision making. We find the title of a recent paper on control instructive as to the importance of this variable on the dynamics of a learning environment: I Lost Control (and My Students Found It) (Schleper, 1993).

7.4.8 Assessment

Traditionally, assessment is an activity undertaken after learning is accomplished: Communicate some knowledge, then test to see if the knowledge has been successfully stored by the learner; demonstrate and coach a skill, then test to see if student can perform skill, etc. A great deal of technology of testing is devoted to enhancing the congruence of the testing context and the learning context. That is, is the test a reliable and valid measure of the extent to which learning has occurred? This approach also seeks to minimize factors that could contaminate test results. For example, a test that simply required the student to repeat answers to questions asked during learning would not be valid. Likewise, if the student were assisted in any way in completing the test, by a person or tool like a calculator, the results would likely be judged as invalid.

Generally speaking, the world of educational measurement adopts physical measurement as a model where a measurement tool quite different from the variable itself is applied: A ruler is applied to measure height, a micrometer is applied to measure thickness, etc. By analogy, an intelligence test measures intelligence but is not itself intelligence; an achievement tests measures a sample of a learned domain but is not itself that domain. Like micrometers and rulers, intelligence and achievement tests are tools (metrics) applied to the variables but somehow distinct from them.

The situation within constructivism is quite different. A rapidly growing literature (e.g., Shavelson, Baxter & Pine, 1992; Belak, Newman, Adams, Archbald, Burgess, Raven & Romberg, 1992; Gifford & O'Connor, 1992; Mabry & Stake, 1994; Linn, Baker & Dunbar, 1990) is introducing such terms as *performance assessment*, *portfolios*, *authentic assessment*, etc., and beginning the process of building a technology of assessment based on constructivist principles such as those proposed in this paper. The distinction between learning and testing is certainly blurred if not rejected in these attempts. For instance, Ann Brown and her colleagues (1993) describe "dynamic assessment," a procedure that shares many characteristics with reciprocal teaching. It too is an example of "assisted learning" (see also Tharp & Gallimore, 1988), where the assessor establishes a zone of proximal development with the student to scaffold new learning as well as assess. Later in the assessment/teaching process, the teacher/assessor withdraws prompts when it is felt that the child can perform independently. Thus, if learning is in the connections, in the activity itself, then learning *is* the test. If the aim of a reading teacher, for example, is to have the child develop the skill of asking questions about reading materials, then the "test" is embedded in the teaching/learning context: Can the student now ask effective questions while reading, whereas previously she was only able to do so with the teacher's support and scaffolding? Or if the aim of the medical school faculty is to have students diagnose and prescribe treatment (and be able to defend their decisions), the test is embedded within the activity, not distinct from it. Ironically, perhaps, when traditional measurement techniques are used in situations such as these, where their applicability is questionable, the scores often show performance at least as good as traditional instruction (Albanese & Mitchell, 1993; Hubbard Welsh, Iatridis, Ficklin & Vaughn, 1994).

Additionally, performance assessment specialists are beginning to develop methods of large-scale assessment of complex performances (e.g., teacher certification—see Delandshire & Petrosky, 1994) that are authentic, discursive, semiotic, and reflexive. It is becoming increasingly clear that assessment that is sympathetic to constructivist principles will require new conceptions of such traditional concepts as reliability and validity (see, for example, Messick, 1989) and of the sorts of evidence that will be helpful in making assessment decisions like who should be employed, hired, admitted to university, and so forth. Of all the areas we have identified, this may be the one that is most underdeveloped (and under development) at this point in time.

7.4.9 Collaborative Learning

Collaborative learning and cooperative learning (see Chapter 35): Everyone wants it. It is *the* instructional strategy, perhaps the strategy of the decade. But why do we have students working together in groups? This is perhaps an area where one's metaphor for learning can most clearly be seen in its impact on the implementation of a strategy. The use of groups may simply be used as an alternative instructional strategy, with little change in the learning goals from traditional didactic instruction (Slavin, 1990; Johnson & Johnson, 1990). The guidelines for using cooperative groups focuses on structural and management variables like the gender distribution, number of participants, etc., and how to ensure that everyone does the work. 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.

Groups also work on problems in the constructivist environment, and the goal in that work is to share alternative viewpoints and challenge as well as help develop each alternative points of view (Cunningham, Duffy & Knuth, 1993; Savery & Duffy, 1995; Sharan & Sharan, 1992). As we noted previously, learning is an inherently social-dialogical process. Hence, our reason for using groups is to promote the dialogical interchange and reflexivity. Our emphasis in providing guidance on the use of groups is how to promote that dialogical interchange among group members. We emphasize the importance of supporting collaborative informal reasoning about problems and reflectivity on the learning process.

7.4.10 Computers and Media

Any Rip van Winkle who has just awakened after 10 years would undoubtedly be overwhelmed by the incredible changes in both the character and the pervasiveness of technology in our society. Video has moved out of the "professional production" limitation and out of the television and movie theaters to become a general medium available for the viewing and analysis of any event. The latest multimedia computers can store enormous amounts of information, present it via sound, text, video, graphics, etc., interact with users in modes that seem evermore natural and complex, and accomplish this with information and people distributed worldwide.

Given the widespread adoption of this technology in education and training, we will consider its role in education in some detail. Most often, technology is adopted by teachers and instructional designers as a "teaching tool," that is, to provide more effective and efficient delivery of instruction and hence more effective and efficient learning. According to this view, the video medium provides richer examples of concepts and principles, and thus we are able to teach the learner better how to execute a procedure, teach to discriminate between examples and nonexamples, etc. Computer technology permits us to build student and expert models (see 19.2.3) so that we can more effectively present problems to the learner and identify and remediate misconceptions (Psotka, Massey & Mutter, 1988). And, of course, the richness of the technology permits us to provider a richer and more exciting (entertaining?) learning environment that will better engage the student in learning the material being presented.

We, on the other hand, want to focus on the technology as a tool for the learner rather than as a tool for the teacher. Let us hasten to clarify, however, that we do not mean to simply substitute "learner" for "teacher" in the previous paragraph: The computer is not, or not only, a tool for the learner to acquire the content or skill more efficiently. Rather, our concern is the new understandings and the new capabilities that are possible through the use of technology. Pea (1985, 1993), in contrasting these two views, describes the first as using technology as a tool simply to amplify what we were doing before (so that we can do it more efficiently and effectively), while the latter is seen as augmenting cognitive activity and thereby leading to a reorganization and extension of our cognition.

One impact of the augmentation view is to examine how the tools may permit the learner to attend to higher-level representations by "off-loading" basic cognitive demands. For example, the use of the word processor permits easy reorganizing of text and hence permits the writer to explore alternative organizations, ways of expressing ideas, etc. It also dramatically impacts the nature of the interaction in collaborative writing activities. Similarly, the calculating functions permit many new foci in mathematics teaching (NCTM, 1989).

In addition to off-loading basic cognitive tasks, the technology may offer genuinely *new* representations or views of phenomena that would not otherwise be possible, and hence provide *new* understandings. Pea (1993) has noted that contribution of scientific visualization techniques to the understanding of particular phenomena (see, e.g., Keller & Keller, 1993). Hay (1994) and Soloway, Guzdial, and Hay (1994) are bringing those visualization techniques into the classroom as a strategy for aiding learners in developing new and richer representations of scientific as well as everyday phenomena. In a related vein, the Vanderbilt group has used video to capture complex activities in ways that allow learners to analyze those complexities and examine the interrelationships (LTGV, 1992). We might also point to the impact of video technology (the ease of recording as well as the ease of random access to and annotation of the video records) on our understanding of dynamic events like teaching and small-group collaboration (Jordan & Henderson, 1994; Brown, 1994).

Within this "augmentation" view, the MAB and MAR models of cognition offer different interpretations or understandings of the technology. The "mind as brain" view, with its focus on the individual mind, sees the computer as enhancing the individual's cognition, focusing on what he or she "knows." As Salomon, Perkins, and Globerson (1991) describe it, it is the effects of computing on the individual's cognitive skills that will impact cognitive performance outside of the computing environment. The effect of computing is an effect that endures beyond the computing, and, as such, this view suggests that knowledge (the residue effect) resides outside of the activity; it is an entity in the head.

From a MAR viewpoint, the technology is seen as an integral component of the cognitive activity. As discussed previously, cognition is distributed in the environment such that an understanding of cognition requires an examination of the activity in the environment. Bateson's famous example of the blind man provides what is to us a very clear example of distributed cognition: how it is impossible to separate tools from cognition:

> Suppose I am a blind man, and I use a stick. I go tap, tap, tap. Where do I start? Is my mental system bounded at the handle of the stick? Is it bounded by my skin? Does it start halfway up the stick? Does it start at the tip of the stick? (1972, p. 459).

The answer to this, of course, depends on the activity of the blind man. In the case of navigating the world, the stick is an integral part of the cognition. However, when Bateson's blind man sits at a computer, the stick's relationship to his cognition has totally changed, and it is keyboards and mouses that become relevant. Cognition is distributed among the artifacts in the activity.

This view of distributed cognition significantly impacts how we think about the role of technology in education and training.[8] The focus is not on the individual in isolation and what he or she knows, but on the activity in the environment (see Table 7-1). It is the activity—focused and contexualized—that is central. Furthermore the task of the learner is no longer seen as static—the computer as applied to the task—but rather it is dynamic: The computer opens new opportunities and makes available new learning activities. As Pea (1993) has noted, our goal becomes one of expanding cognition, not of reallocating cognitive activity as a division of labor.

A good example of the use of technology to expand cognition is found in George Landow's (1992) argument for the design and use of hypermedia (see 21.4). Landow has been perhaps the most outspoken advocate of hypermedia technology, for he sees it as a medium that permits critical theorists to realize and test their views as never before possible. His views on the important relation between hypertext and critical theory is clear in the following statements:

> A paradigm shift, I suggest, has begun to take place in the writings of Jacques Derrida and Theodor Nelson, of Roland Barthes and Andries van Dam. I suspect that one name in each pair will be unknown to most of my readers. . . . [However] all four, like many others who write on hypertext or literary theory, argue that we must abandon conceptual systems founded on ideas of center, margins, hierarchy, and linearity, and replace them with ones of multilinearity, nodes, links, and networks. Almost all parties to this paradigm shift, which marks a revolution in human thought, see electronic writing as a direct response to the strengths and weaknesses of the printed book. This response has profound implications for literature, education, and books. . . . Using hypertext, we will have, or now already have, a new laboratory . . . in which to test their ideas. . . . [While] critical theory promises to theorize hypertext, hypertext promises to embody and thereby test aspects of theory, particularly those concerning textuality, narrative, and the roles or functions of reader and writer (1992, pp. 2–3).
>
> . . . hypertext has much in common with some major points of contemporary literary theory and semiological theory, particularly with Derrida's emphasis on de-centering (see 10.5) and with Barthe's conception of the readerly vs. the writerly text. In fact hypertext creates an almost embarrassingly literal embodiment of both concepts (1992, pp. 33–34).

In essence, Landow is arguing that hypertext can be used to empower the reader to see and use text in new ways and in particular to support multilineal thinking. A goal of critical theory is to permit the reader his or her own center for investigation, not only in terms of starting points but also in terms of the consideration of the information and the paths along which those considerations might lead (see 9.2, 10.5.3). Thus a major goal in critical theory is to decenter the author and the text, to unconstrain the linkages of ideas from the linear flow of text and from the "container" of the book covers, and to place the authority for constructing and evaluating ideas in the reader and his or her collaboration with other readers.

We would suggest, with the proliferation of information in this information age, that such decentering will become essential to successful problem solving and thought in many domains. Success will increasingly depend on exploring interrelationships in an information-rich environment rather than on accepting the point of view of one author who pursued one set of relationships and presents conclusions reflecting his or her implicit biases. While we tend to think of books as "natural" ways of representing information and ideas, Landow reminds us that it is an artificial structure that may not serve our present needs:

> "The structure of books," Tom McArthur reminds us, "is anything but 'natural'—indeed, it is thoroughly *un*natural and took all of 4,000 years to bring about. The achievement of the Scholastics, preeminently among the world's scribal elites, was to conventionalize the themes, plots, and shapes of books in a truly rigorous way" (Landow, 1992, p. 57).

In essence, the design of the text imposed order on fragmented knowledge and ideas. Hypertext would remove the textual imposition of order, and, Landow argues, the reader would create his or her own order based on scientific, historical, cultural, or any other thematically coherent focus. The consistency of Landow's view of hypertext with our constructivist MAR model is clear:

> The hypertextual dissolution of centrality, which makes the medium such a potentially democratic one, also makes it a model of a society of conversations in which no one conversation, no one discipline or ideology, dominates or founds the others. It is thus the instantiation of what Richard Rorty terms the edifying philosophy, the point of which is to keep the conversation going rather than to find the objective truth" (Landow, 1992, p. 78).

Within Landow's framework, the diversity of "multilinearity" of a hypertext is critical, as is the availability of search tools and the ability of the reader to create his or her own links and nodes so as to find and create links and nodes

---

[8]Our focus here is on technology, but of course the view applies to other individuals in the environment, e.g., the role of collaboration, and the entire sociocultural context of the activity.

in the process of constructing reader-centered themes. Landow (1989a, 1989b) illustrates the educational realization of his view of hypertext in the teaching of his undergraduate and graduate courses in literature where students work in a hypertext database consisting of thousands of nodes and linking to other hypertext databases. Student's assignments establish themes for which they must construct alternative interpretations, e.g., as to how two authors or two passages are similar, which may involve issues of the social or cultural characteristics of the time, early experiences of the authors, the formalities of plot development, etc. Rather than there being a "true" reason or interpretation, Landow encourages his students to recognize the multicausality and the importance of focus on interpretation.

Landow's use of hypertext in his literature courses provides an example of the use of technology to augment cognition and in the evolution of the learning task that the technology permitted. This is a considerably different view from that of a traditional "instructional" view of hypertext where the concern is whether the student will cover the material and where tools are designed to restrict access until prerequisites are "covered" or to guide the student through prespecified paths. In concluding this discussion, we would like to describe briefly two additional examples of this "constructivist" view of effective uses of technology.

First, a most obvious example is the use of the Internet and other wide-area networks to promote collaboration (see 14.1, 14.2, and 14.7). We have multiple examples of the use of the network to create international as well as scientific collaboration to help students take a less parochial view of issues, to help them to see and evaluate multiple perspectives, and to engage them in more authentic research activities (see, e.g., Roupp, 1993). On a more local level, Harasim (1993) has demonstrated the use of the Internet as a vehicle to promote collaboration among students in a distance education course. Most distance education programs use technology, if it is available, to deliver instruction, emphasizing the transmission of the content rather than collaboration. In contrast, Harasim made the dialogic central in her distance education course. Materials were distributed via the mail, and the Internet was used for formal seminar discussions and for informal exchanges in a virtual café. Just as would be expected in any on-site seminar, students were expected to discuss the seminar topic, and grading was based in part on their contribution to that discussion. There was no formal, didactic instruction.

Finally, Strategic Teaching Framework,[9] (STF) provides an example of the use of multimedia in teacher education that honors the teacher as problem solver or researcher (Duffy, 1995). The goal of STF is to aid teachers in adopting a learner-centered, problem-solving, collaborative approach to learning, i.e., an approach based on constructivist principles. Typical technology-based approaches to teacher change use video to present alternative scenarios that the teacher can respond to and then receive the "correct" response, or scenarios illustrating "the" correct method by examples and nonexamples. STF, in contrast, views teaching holistically rather than as a set of discrete methods. Additionally, it is designed under the assumption that adopting a learner-centered view requires a conceptual change in addition to the development of new strategies. Finally, it was assumed that teachers must construct and test their own understanding of methods and that construction must arise from their own evaluation of teaching.

This framework led to the design of STF based on the metaphor of visiting an ongoing classroom. If a teacher wanted to adopt new approaches to teaching, he or she would visit the classroom of experienced teachers, observe their teaching, ask questions, and explore different aspects of their approach. There would be multiple points of view expressed about what was important in the teaching process, and the teacher-learner would have to evaluate those perspectives. The teacher-learner would return to his or her classroom, test the strategies and views, and then, in an iterative process, return to the "mentors" classroom to observe more and ask additional questions. Ideally this teacher would be part of a community of teachers, all attempting to restructure their teaching, and the constructive dialogue would occur among members of this community.

STF, then, does not teach; rather it is a resource for learning. It consists of videos of classrooms the teacher-learner can visit. These are not brief scenarios, but rather an entire class episode, typically 50 minutes long. As teacher-learners sit in on the class, they may ask for points of view as to what is important instructionally at any particular point in the video. The learners have multiple perspectives available: the teacher they are observing, an experienced teacher-educator, or a researcher. Furthermore, the comments may address management, teaching, or assessment issues. Just as with the classroom video, none of the perspectives is scripted. They are straightforward comments from each "expert" as to what she or he thinks is important at that particular point in the class. Thus, this is an authentic interaction, both in visiting the classroom and in soliciting perspectives. While there is more to STF (a whole library of resources), this brief description illustrates the use of multimedia and, in particular, the richness of video, as a tool for the learner focused on constructing understanding rather than as a tool for the teacher (or instructional developer) to transmit knowledge.

7.5 AN INSTRUCTIONAL MODEL

In concluding this chapter we will describe problem-based learning, an instructional model that we feel exemplifies the constructivist theory represented by our MAR metaphor. There are numerous instructional models popular today that focus on "problems." Case-based learning, modeled after the traditions of business and law school (Christensen, 1987; Spizzen & Hart, 1985; Stevens, 1983), is perhaps the most

[9]The development of Strategic Teaching Framework is a joint effort of Indiana University and the North Central Regional Education Laboratory.

widespread and popular approach to problem-centered instruction (Greenwood & Parkay, 1989; Merseth & Lacey, 1993; Sykes & Bird, 1992; Wasserman, 1993). In this approach, instruction is centered around a description of some event that took place and that is relevant to the professional activities of the learners: an instructional scenario for teachers, a legal case for lawyers, etc. In business and industry, the instructional models for using problems are goal-based scenarios (Collins, 1994; Nowakowski, 1994) and action learning (Froiland, 1994). Both begin with a problem—a goal- or action-oriented decision the individual must make—but while the goal-based scenario model (see 20.33) uses problems from the past or specially created problems, action learning focuses on a real problem currently requiring action by one or more of the learners. It is, in essence, just-in-time training. Finally, at the elementary education level, the "problems" in the project-based learning model (Katz & Chard, 1989) involve a multidisciplinary (subject matter) exploration of a topic (e.g., trains) in which the students examine the topic from multiple perspectives over a week or more.

Problem-based learning as a specific instructional model was first implemented in medical education in the early 70s (see 20.3.4) and, like the models listed above, it too is based on presenting problems for the students to work on. It is not our goal to try to contrast the instructional models represented by cases/goals/projects/actions/problems. Indeed, there is so much variation in the implementation of each of these models that there is likely to be as much similarity between some implementations from different models than there is between different implementations within the same model (see, e.g., Barrows, 1986; Froiland, 1994; Williams, 1992).

A central theme to our chapter has been that an instructional designer's grounding assumptions about knowledge and learning are primary determinants of the instruction that is designed. So it is here. While there is widespread agreement as to the role of problems in instruction, the agreement is not so great in terms of the learning goals or assumptions about learning that surround the use of problems. We can identify five strategies for using problems that reflect different assumptions about either what is to be learned or how learning occurs.

1. *The Problem as a Guide.* Here the problem serves as a concrete reference point to focus the learner's attention. Reading assignments are given along with the case, and the readers are told to think of the reading in terms of the case. The case gives meaning to the reading assignment. This is similar to the study skill strategy of presenting questions at the start of the chapter to guide reading.

2. *The Problem as an Integrator or Test.* Here the problem is presented after the assigned readings are completed and perhaps even after they are discussed. The goal is to apply the knowledge from reading to the case to see how well the readings were understood and to aid the transfer process from learning to application. This is similar to presenting study or review questions at the end of the chapter.

3. *The Problem as an Example.* Here the problem is simply another bit of instructional material and is integrated in the reading. It is used to illustrate some particular point, and this is likely to be done through lecture or "teaching" as it is through student discussion. The focus is on the principle, concept, or procedure illustrated in the problem.

4. *The Problem as a Vehicle for Process.* Here the focus on critical thinking in relation to the problem is central. The problem becomes a vehicle for training thinking skills. Thus, heuristics for problem analysis are taught in relation to the problem. The goal is to develop thinking skills, not only to solve the problem.

5. *The Problem as a Stimulus for Authentic Activity.* Here the focus is on developing the skills related to solving the problem as well as other problems like it. Rather than "teaching" the skills, the skills are developed through working on the problem, i.e., through authentic activity. The "skills" here include physical skills, gathering and bringing knowledge in the domain to bear on the problem, and metacognitve skills related to all aspects of the problem-solving process.

It is this last use of problems, the problem as a stimulus for authentic activity, that is our focus. It is the approach developed by Howard Barrows for medical education in the early 70s and which he has continued to develop and refine (Barrows, 1985, 1992, 1994). This approach is founded on the goal of engaging and supporting the learner in activities that reflect the demands of professional practice. Rather than "teaching" the student in the sense of presenting or even assigning information, the goal is to support the student's learning. From our perspective, the focus is rightly on the activity of the learner in the content domain. That is, it is impossible to describe what is learned in terms of the activity alone or in terms of the content alone. It is not that students are learning critical-thinking skills, self-directed learning skills, or collaborative learning skills, nor is it that they are learning "the" content domain. Rather, it is the activity in relation to the content that defines learning: the ability to think critically in that content domain, to collaborate with peers and use them to test ideas about issues, and the ability to locate information related to the issues and bring it to bear on the diagnosis.

We should emphasize that while problem-based learning (PBL) has been developed for professional training, it clearly has generality to all levels of education. A grounding assumption is that we do not learn in a content domain simply to acquire information but rather to bring that information to bear on our daily lives. Thus, consistent with the goals advocated by Dewey (1916, 1938), the argument in PBL is that learning in school should model and prepare us for the self-directed learning we will need to do to be effective participants in our community and to be effective in our profession. For example, in working with high schools, Barrows and Myers (1993) designed problems that related to the flooding in the Midwest in 1993, the action that government should take to monitor asteroids in space, and an analysis of how the geography of the Middle East impacts the conflicts between nations in that area.

The problems Barrows and Myers generated for the high school level may sound very much like topics that might be used in *theme-based instruction*. Indeed, PBL is theme based in the sense that learning is organized around the problem rather than around subject matter. However, once again we must emphasize that the critical characteristic for us is that the teacher in PBL does not teach students what they should do/know and when they should do/know it. Rather, the teacher is there to support the students in developing their critical-thinking skills, self-directed learning skills, and content knowledge in relation to the problem. The teacher must honor and support the students' thinking rather than impose structure on it. (We note, of course, that honoring the students' thinking will include challenging that thinking.)

7.5.1 The PBL Process

Problem-based learning can perhaps best be understood through a brief description of the learning/instructional process as implemented by Barrows (1985, 1992, 1994) in a medical school. When students enter the medical school, they are divided into groups of five, and each group is assigned a facilitator. The students are then presented a problem in the form of a patient entering with presenting symptoms. The students' task is to diagnose the patient and be able to provide a rationale for that diagnosis and recommended treatment.

The students begin the problem "cold"—they do not know what the problem will be until it is presented. They discuss the problem, generating hypotheses based on whatever experience or knowledge they have, identifying relevant facts in the case, and identifying learning issues. The learning issues are topics of any sort that are deemed of potential relevance to this problem and which the group feels they do not understand as well as they should. A session is not complete until each student has an opportunity to reflect verbally on his or her current beliefs about the diagnosis (i.e., commit to a temporary position) and assume responsibility for particular learning issues that were identified. Note that there are no prespecified objectives presented to the students. The students generate the learning issues (objectives) based on their analysis of the problem.

After the session, the students all engage in self-directed learning. There are no assigned texts. Rather the students are totally responsible for gathering the information from the available medical library and computer database resources. Additionally, particular faculty are designated to be available as consultants (as they would be for any physician in the real world). The students may go to the consultants seeking information.

After self-directed learning, the students meet again. They begin by evaluating resources: what was most useful and what was not so useful. They then begin working on the problem with this new level of understanding. Note that they do not simply tell each other what they learned. Rather, they use that learning in reexamining the problem. This cycle may repeat itself if new learning issues arise. Problems in the medical school program last anywhere from a week to 3 weeks.

Assessment at the end of the process is in terms of peer evaluation and self-evaluation. There are no tests in this medical school curriculum. The assessment includes self- and peer evaluation (with suggestions for improvement) in three areas: self-directed learning, problem solving, and skills as a group member. While the students must pass the Medical Board exam after 2 years, this is outside of the curriculum structure.[10] However, tests as part of the PBL curriculum are not precluded. For example, one high school teacher we know who uses the PBL approach designs traditional tests based on what the students have identified as learning issues. Thus, rather than a prespecification of what is to be learned, the assessment focuses on the issues the learners have identified.

7.5.2 Key Issues in Designing PBL Instruction

7.5.2.1. Task Analysis. In designing a problem-based learning curriculum, as with any curriculum, we must begin with an analysis of what must be learned. However, in doing this, the developer must combine identification of the *key* concepts, procedures, etc., with an analysis of the professional (or "good citizen") use of those concepts. Identification of key concepts is a matter of expert statements of what is most important for students to "know." In both the Ohio University Business School (Milter & Stinson, 1993) and the Southern Illinois University Medical School (Barrows, 1985), this involved going to faculty teaching the traditional courses and asking them to identify the key things a student should learn in their course. This naturally requires extensive negotiation and specification. However, it does not involve the analysis of that key information into underlying learning requirements. That is, the task analysis stops at the top level and only identifies key concepts. What must be understood about the key concepts is defined through the professional activity that calls for their use; that is, it is defined in the activity of the learner. In the medical profession, the activity has to do with diagnosing and treating patients with presenting symptoms. In the business school, the professional activity has to do with business analysis and decision making.

There are two points we wish to emphasize here. First, this analysis does not preclude any type of learning activity—memorization of a list or extensive practice of a skill may be necessary—but it should arise out of the need to use the

[10]PBL students do as well as traditional students in a variety of discipline areas on standard or board-qualifying exams. The PBL students seem to retain their knowledge longer after the exam than students in traditional classes (Albanese & Mitchell, 1993).

information in authentic tasks. Second, what must be learned includes not only information in the content domain but also metacognitive, collaborative, and other skills as are necessary for participating in authentic activity.

At Indiana University we have recently introduced an undergraduate minor in Corporate and Community Education (CCE) (Duffy, 1994). The goal of the minor is to develop the skills related to carrying out effective informal education related to community and professional needs. As part of the minor, the students take three core courses, all of which use a problem-based learning approach that involves the students in authentic educational problems. The skills

TABLE 7-2. PRELIMINARY ANALYSIS OF THE SKILLS AND KNOWLEDGE REQUIRED IN THE CORPORATE AND COMMUNITY EDUCATION PROGRAM AT INDIANA UNIVERSITY

I. Analyzing problems. Given a potential corporate or community education problem, how effective are you in analyzing that problem, deciding what needs to be done, and developing a plan of action? This includes your ability to:

- Work collaboratively in a group as both a leader and a group member, carrying your weight in the problem-solving activity, and listening to and respecting alternative points of view.
- Think critically about a problem, analyzing it into subproblems with some rationale.
- Evaluate alternative perspectives and prioritize the perspectives on the problem, including the perspectives of the various stakeholders.
- Design a work strategy addressing the sequence of activity, time requirements, and resource requirements.
- Use project-planning tools to manage your work.
- Monitor and adjust strategies as needed.

II. Managing your learning. Given the analysis of a problem, how well can you identify and refine learning issues, locate resources relevant to those issues, and use those resources to obtain the information that will bear on the problem? This includes your ability to:

- Identify potentially relevant types of information resources and evaluate the usefulness of the resources after learning.
- Allocate the time necessary to achieve your self-directed learning objective.
- Sort through many relevant documents that express multiple perspectives, identifying relevant information and developing criteria for determining what information to use.

III. Use of information resources. Given a learning issue, how efficiently can you use the variety of information repositories to identify and obtain potentially relevant information? This includes your ability to:

- Locate and acquire information or expertise from the library, experts, and using electronic resources like e-mail, World Wide Web, and Newsreaders.
- Reformulate your learning issue in a way appropriate to searching, using the particular information resource, i.e., ability to develop key words, restrict searches, identify related topics, etc.

IV. Conduct audience/need analysis. Given a potential corporate or community education requirement, how well can you use the various strategies for evaluating the information needs? This includes your ability to:

- Determine what information needs to be collected about the audience.
- Design and evaluate alternative information collection strategies, e.g., phone interviewing, mail survey, door-to-door interview, questionnaires, etc.
- Implement an actual information collection strategy including determining strategies for sampling and accessing people.
- Analyze and summarize the results of the audience and needs analysis to make recommendations on information needs and delivery strategies.

V. Designing and delivering usable information. Given the need to educate a group on some issue, how well can you use the necessary tools to design and deliver information that meets the information need? This includes your ability to:

- Develop a rationale for a delivery strategy, content specification, and content layout to meet the information need.
- Apply rhetorical, graphic design, document design, interface design, instructional design, speech communication, teaching, and adult literacy principles as appropriate to the preparation of the document.
- Use the various computer- and video-based tools as appropriate to the design and delivery.

VI. Assess effectiveness of your performance and your products. The goal here is to develop the ability to monitor and adjust as necessary your performance in each of the five areas described above. More generally, this goal can be phrased as one of becoming a reflective practitioner and includes your ability to:

- Reflect on your activities and evaluate strengths and weakness and, based on that, develop strategies to increase your effectiveness.
- Ability to solicit and use feedback from others on your performance.
- Ability to design and implement strategies for evaluating your products and for using that evaluation to assess alternative design or development approaches.

and knowledge identified as critical in the CCE program and which guide the development of the problems in each of the core courses are outlined in Table 7-2.[11] These are the skills and knowledge that the students should develop over the course of the program.

7.5.2.2. Problem Generation. The content for the course rests in the problem that is generated. It determines what the students must learn. There are two guiding forces in developing problems. First, the problems must raise the concepts and principles relevant to the content domain (as defined by the task analysis). Second, the problems must be "real." There are three reasons for this. (1) Because the students are open to explore all dimensions of the problem there is considerable difficulty in creating a rich problem with a consistent set of information. (2) Real problems tend to engage learners more; there is a larger context of familiarity with the problem. (3) Students want to know the outcome or current status of the problem and tend to be disenfranchised when told it is not a real problem.

In the case of the medical school, a real problem means the case is based on a real patient, not necessarily a current patient, but not someone fictitious for whom symptoms are made up. In the business curriculum, this means that the problem is a current business problem; e.g., 3 years ago a problem that was meant to engage the students in particular concepts was "Should AT&T buy NCR?" The parallel problem last year was "Should Merck buy Medico?" (Stinson, 1994). For our corporate and community education course, the first problem,[12] one that will consume an entire semester, is stated as follows:

> About 15 years ago in Bloomington, a sludge byproduct of Westinghouse's manufacturing process was distributed around the community as a mulch rich in nitrogen. However, it was soon determined that the sludge was contaminated with PCBs, a chemical thought to be a significant carcinogen. The sludge has been gathered into piles and covered with tarps or concrete, though there are thought to be numerous sites around the county that are still contaminated.
>
> For the last 15 years there have been numerous proposals as to how to dispose of the PCBs, but no action as yet has been taken. Interestingly, the public has been apathetic about this potentially very serious issue. This past summer the EPA set up eight, 2-hour public meetings to discuss disposal of the PCBs. However, because of lack of response, they cut it back to two meetings, and then only 14 people showed up at one of those meetings. Another forum held this November was also sparsely attended. In both cases, the meetings received minimal press coverage.
>
> As responsible members of this community we are concerned that the PCBs are still scattered around Bloomington after all these years, and the public does not seem to care. We are going to design educational materials that will:
>
> - Provide the information the citizens need to make a reasonable decision or to discuss alternatives that will lead to cleaning up the PCBs
> - Present that information in such a way that the citizens will be motivated to actively participate in decision making regarding the PCBs.

7.5.3.3. The Learning Sequence. In this sequence, problem-based learning cycles go through two types of learning activities: collaborative problem analysis sessions and self-directed learning. The collaborative problem analysis session usually occurs with small groups of about five, supported by a facilitator. However, with modifications, this can be a mixture of large- and small-group activities (Milter & Stinson, 1993). In our corporate and community education program, we will use a jigsaw model. In the first stage of the jigsaw, the focus is on developing content expertise related to the problem area—PCBs in the case of the problem outlined above. The whole class will first work to identify learning issues in the content area, and then small groups assume responsibility for particular issues. They develop expertise on those issues and then share that expertise in large-group problem solving where all the expertise is brought to bear on the problem. Then as the class moves to the second stage of identifying the instructional strategy and designing the product, the groups will be redefined so that product development groups will consist of students having content expertise on different issues.

The sessions are student-run, problem-solving sessions in which hypotheses and action plans are generated, along with facts that support or refute the hypotheses and learning issues that must be addressed after the session. The learning goals underlying the design of these sessions include developing informal or hypothetico-deductive reasoning skills, reflective and metacognitive skills, and collaborative skills and content knowledge as other members of the group bring their content knowledge to bear on the problem.

In self-directed learning, the students seek and use resources that will address the issues they need to learn about. This is considerably different from learning activities in traditional instruction, where the reading is assigned by the instructor and the task is to learn what is in the text. In the PBL format, the students are learning how to identify, locate, and evaluate information resources as well as use those resources as tools in solving problems, rather than as ends in and of themselves. Interestingly, at all levels of schooling, the problem-based learning tends to lead the learners to primary sources, with secondary sources like textbooks being rejected as too vague or not current (Barrows, personal communications; Duffy & McMahon, 1992).

7.5.3.4. Facilitator Role. In his discussion of the tutorial process, Barrows states:

> The ability of the tutor to use facilitory teaching skills during the small-group learning process is the major determinant of the quality and success of any educational method aimed at (1) developing students' thinking or reasoning skills (problem solving, metacognition, critical thinking) as they learn, and (2) helping them to become independent and

[11]We would like to thank Doug Harper, Karen St. Rain, John Savery, Chuck Palenik, Melanie Harper, and Larry Mikulecky for their help in developing this skill and knowledge analysis.

[12]We would like to thank John Savery and Hugh Kremer for their contributions in developing this problem.

self-directed (learning to learn, learning management). Tutoring is a teaching skill central to problem-based, self-directed learning" (1992, p. 12).

Throughout a session the facilitator models higher-order thinking by asking questions that probe students knowledge deeply. To do this, the facilitator constantly asks Why? What do you mean? How do you know that's true? The facilitator's interactions with the students remain at a metacognitive level, and he or she avoids expressing an opinion or giving information to the students.

A second facilitator role is to challenge the learner's thinking. The facilitator (and hopefully the other students in this collaborative environment) will constantly ask: Do you know what that means? What are the implications of that? Is there anything else? Superficial thinking and vague notions do not go unchallenged. During the first few PBL sessions, the facilitator challenges both the level of understanding and the relevance and completeness of the issues studied. Gradually, however, the students take over this role themselves as they become self-directed learners.

7.5.3.5. Assessment. Assessment must be in the context of the problem the students are working on. There are numerous strategies for accomplishing this. Mildred Jackson, a high school science teacher at Choctaw County High School in Butler, Alabama, uses problem-based learning for the majority of her science instruction—with the reading materials being located by the students based on their learning issues. That is, there is no assigned reading. Butler simply uses for her testing what the students identify as learning issues. The text may be multiple choice, essay, or short answer; the critical characteristic is that it is generated from the students' learning issues.

Barrows relies entirely on student self- and peer assessment. However, the assessment is ongoing, rather than just being an end of the semester rating. Thus, while the students may be easy on one another initially, as they continue working on problems, they clearly begin to provide ratings and feedback to fellow group members more reflective of their contributions.

We also rely heavily on peer and self-assessment in the corporate and community education program. As noted in Table 7-2, the abilities to self-assess and to provide constructive feedback to team members are explicit learning goals, and this is not only an assessment process but also a learning process. Every other week, students assess themselves in terms of their skills as a problem solver, as a self-directed learner, and as a team member. They are provided guidance on the skills and knowledge development issues (Table 7-2) they should be considering in each of these categories. They also evaluate themselves by describing their learning over the last two weeks.

The self-evaluations are distributed to the instructor and to the team members. During the following week (the alternating weeks), the team members will provide feedback to the other team members as to how they performed—that is, they will examine the self-assessments for each team member and offer feedback, including suggestions on how they might improve their performance. These peer evaluations are sent to the instructor, who integrates them and presents them to the individual students, thus providing anonymity in the peer evaluation process. While we would prefer open evaluations, we recognize that it is something we must work toward over the course of the curriculum.

The Indiana University Northwest Medical Center presents an interesting variation on the assessment strategy. While it has a PBL program, because it is part of a larger system, it was required to administer unit tests every 6 weeks that "covered" the subject-matter focus for that period. In discussions the first author had with the instructors, they reported that students worked hard and enjoyed the problems, but that after each problem some of the students would pester the instructor, asking, "That was all very good, but what do I really have to know for the test?" This became an ongoing problem for the instructors. In response, the dean of the center took the test development out of the hands of the instructors. Rather than developing a test, they purchased the unit test from another medical school, a different test each time so that even the instructors did not know what school the tests came from.[13]

7.6 LEARNING IN THE RHIZOME

In his popular novel *The Name of the Rose*, Umberto Eco (1983) describes a medieval library, a labyrinth of passages, stairways, and chambers filled with books. The library is a rhizome (as much as any actual existent thing can represent "an inconceivable globality"!), and learning is illustrated by Brother William, the main character of the novel, feeling and groping his way through the library. As Brother William constructs a path (or pattern of connections) through the library, one of only many possible paths, he is transforming his means of participating in the community of scholars, both those using the library (constructing their own paths) and those who have written manuscripts contained therein. Brother William is moving from legitimate peripheral to centripetal participation, learning the activities that will allow him to be effective in that community. In our view, he is *not* acquiring and internalizing, *not* building an abstract mental representation of the library and its contents.

Our responsibility as educators and instructional designers has traditionally been conceived of as efficient communication and motivation, as individuals knowledgeable in a subject-matter domain and/or skilled in communicating that content and provoking interest in it. The systematic approaches to design of instruction which dominate our field are disposed to find empirically valid, tried, and true methods for accomplishing those ends.

[13]We do not have the performance scores for students on these tests. However, before the PBL program, the Northwest students' performance on the MCAT exam was average for the eight-campus Indiana University system. After 2 years of the PBL program, the average performance of the Northwest students exceeded that of the other seven campuses (Albanese & Mitchell, 1993; Hubbard Welsh, Eatridis, Ficklin & Vaughn, 1994).

Under the assumptions discussed in this paper, however, educators and instructional designers become guides or supports for students as they struggle with constructing their connections to and with a sociocultural context. Rather than empirically validated generalizations about effective instructional strategies, constructivists look to develop support structures embedded in the problem tasks themselves, tools that may both support and transform participation, and outcomes, the attainment of which are their own reward. As Lakoff (1987) has put it:

> How we understand mind . . . matters for what we value in ourselves and others—for education, for research, for the way we set up human institutions, and most important for what counts as a humane way to live and act . . . If we fully appreciate the role of the imaginative aspects of reason, we will give them full value, investigate them more thoroughly, and provide better education in using them. Our ideas about what people can learn and should be learning, as well as what they should be doing with what they learn, depend on our concept of learning itself. It is important that we have discovered that rational thought goes well beyond the literal and the mechanical. It is important because our ideas about how human minds should be employed depend on our ideas of what a human mind is (Lakoff, 1987, p. xvi).

REFERENCES

Albanese, M. A. & Mitchell, S. (1993). Problem based learning: a review of the literature on its outcomes and implementation issues. *Academic Medicine 68*, 52–81.

Baron, J. & Sternberg, R., eds. (1987). *Teaching thinking skills.* New York: Freeman.

Barrows, H.S. (1986). A taxonomy of problem based learning methods. *Medical Education 20*, 481–86.

— (1992). *The tutorial process.* Springfield, IL: Southern Illinois University School of Medicine.

— (1994). *Practice-based learning: problem-based learning applied to medical education.* Springfield, IL: Southern Illinois University Medical School.

— & Myers, A.C. (1993). *Problem-based learning in secondary schools.* Unpublished monograph. Springfield, IL: Problem-Based Learning Institute, Lanphier High School and Southern Illinois University Medical School.

— (1985). *How to design a problem-based curriculum for the preclinical years.* New York: Springer.

Bateson, G. (1972). *Steps to an ecology of mind.* New York: Ballentine.

Bednar, A., Cunningham, D.J., Duffy, T. & Perry, D. (1991). Theory into practice: how do we link? *In* Anglin, G., ed. *Instructional technology: past, present and future*, 88-101. Englewood, CO: Libraries Unlimited.

Bereiter, C. (1985). Toward a solution of the learning paradox. *Review of Educational Research 55*, 201–26.

— (1994). Implications of postmodernism for science, or, science as progressive discourse. *Educational Technology 29*, 3–12.

Berlak, H., Newman, F., Adams, E., Archbald, D., Burgess, T., Raven, R. & Romberg, T. (1992). *Toward a new science of educational testing and assessment.* New York: SUNY Press.

Bornstein, A. (1979). *Memory.* Dubuque, IA: Kendall/Hunt.

Bransford, J. & Stein, B. (1984). *The IDEAL problem solver.* New York: Freeman.

Brooks, J. & Brooks, M. (1993). *In search of understanding: the case for constructivist classrooms.* Alexandria, VA: Association for Supervision and Curriculum Development.

Brown, J.S., Collins, A. & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher 18*, 32–42.

Brown, Ann, Ash, D., Rutherford, M., Nakagawa, K., Gordon, A. & Campione, J. (1993). Distributed expertise in the classroom. *In* G.Salomon, ed. *Distributed cognitions.* New York: Cambridge University Press.

Bruner, Jerome (1961). The act of discovery. *Harvard Educational Review 31*, 21–32.

— (1966). *Towards a theory of instruction.* Cambridge, MA: Harvard University Press.

— (1971). The process of education revisited. *Phi Delta Kappan 20*, 18–21.

— (1990). *Acts of meaning.* Cambridge, MA: Harvard University Press.

— & Dow, Peter (undated). *Man: a course of study: a description of an elementary social studies curriculum.* Cambridge, MA: Educational Development Center.

Christensen, C.R. (1987). *Teaching and the case method: test, cases, and readings.* Boston, MA: Harvard Business School.

Cobb, P. (1994a). *Where is the mind? Constructivist and sociocultural perspectives on mathematical development.* Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

— (1994b). Where is the mind? Constructivist and sociocultural perspectives on mathematical development. *Educational Researcher 23*, 13–20.

Cognition and Technology Group at Vanderbilt (1992). Technology and the design of generative learning environments. *In* T. Duffy & D. Jonassen, eds. *Constructivism and the technology of instruction: a conversation.* Hillsdale, NJ: Erlbaum.

Cole, Henry G. & Lacefield, Warren (1980). *MACOS: its empirical effect versus its critics.* Paper presented at the annual meeting of the American Educational Research Association. Montreal, Quebec.

Cole, M. & Engestrom, Y. (1993). A cultural-historical approach to distributed cognition. *In* G. Salomon, ed. *Distributed cognitions.* New York: Cambridge University Press.

— (1985). The zone of proximal development: where culture and cognition create each other. *In* J. Wertsch, ed. *Culture, communication and cognition: Vygotskian perspectives.* New York: Cambridge University Press.

Collins, A. (1994). Goal-based scenarios and the problem of situated learning: a commentary on Andersen Consulting's design of goal-based scenarios. *Educational Technology 34*, 30–32.

Conlan, John (1975). MACOS: the push for a uniform national curriculum. *Social Education*, 388–92.

Cuban, L. (1991). Informal reasoning and instruction: a commentary. *In* J. F. Voss, D. Perkins & J. Segal, eds. *Informal reasoning and education.* Hillsdale, NJ: Erlbaum.

Cunningham, D.J. (1986). Good guys and bad guys. *Educational Communication and Technology Journal 34*, 3–7.

— (1991). Assessing constructions and constructing assessments. *Educational Technology 31*,(5) 13–17.

— (1991). In defense of extremism. *Educational Technology 31*(9), 26–27.

— (1992). Beyond educational psychology: steps toward an educational semiotic. *Educational Psychology Review 4*, 165–194.

— (1992). Everything said is said by someone. *Educational Psychology Review 4*, 261–67.

— (1994). Discussion and dialogue in education for mutual understanding. *In* S. Gamagi, ed. *Assimilation, pluralism and multiculturalism*, 195-205. Armidale, Australia: University of New England Press.

—, Duffy, T. & Knuth, R. (1993). The textbook of the future. *In* C. McKnight, A.Dillon & J. Richardson, eds. *Hypertext : a psychological perspective*, 19–50. Chichester: Horwood.

— and Knuth, R. (1993). Tools for constructivism. *In* T. Duffy, J. Lowyck & D. Jonassen, eds. *Designing environments for constructive learning*, 163–88. Berlin: Springer.

—, Knight, B. & Watson, K. (1994). Instructional prescriptions can be hazardous to your pedagogy. *Journal of Accelerative Learning and Teaching 19*, 17–44.

—, McMahon, H. & O'Neill, W. (1992). Bubble dialogue: a new tool for instruction and assessment. *Educational Technology Research and Development 40*, 59–67.

Deely, J. (1982). *Introducing semiotic*. Bloomington, IN: Indiana University Press.

Delandshere, G. & Petrosky, A. (1994). Capturing teachers' knowledge: performance assessment,(a) and post-structuralist epistemology, (b) from a post-structuralist perspective, (c) and post-structuralism, (d) none of the above. *Educational Researcher 23*, 11–18.

Deleuze, G. & Guattari, F. (1983). Rhizome. *In* G. Deleuze & F. Guattari, eds. *On the line*. New York: Semiotext(e).

Dewey, John (1916). *Democracy and education*. New York: Macmillan.

— (1929) *My pedagogical creed*. Washington, DC: Progressive Education Association.

— (1938). *Experience and education*. New York: Macmillan.

Dow, Peter (1975). MACOS revisited: a commentary on the most frequently asked questions about "Man: a course of study." *Social Education*, 388–96.

Driver, R., Asoko, H., Leach, J., Mortimer, E. & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher 23*, 5–12.

Duffy, Thomas M. (1994). Corporate and community education: achieving success in the information society. Unpublished paper. Bloomington, IN: Indiana University.

— (1995). Strategic teaching frameworks: an instructional model for complex, interactive skills. *In* C. Dills & A. Romiszowski, eds. *Instructional development state of the art, Vol. 3: Paradigms*. Englewood Cliffs, NJ: Educational Technology.

Duffy, Thomas M. & Jonassen, D., eds. (1992). *Constructivism and the technology of instruction: a conversation*. Hillsdale NJ: Erlbaum.

— & Knuth, R. (1990). Hypermedia and instruction: where is the match? *In* D. Jonassen and H. Mandl, eds. *Designing hypermedia for learning*. Heidelberg, FRG: Springer.

—, Lowyck, J. & Jonassen, D., eds. (1993). *Designing environments for constructivist learning*. Heidelberg: Springer.

— & McMahon, Teresa (1992). The Buddy System project: four case studies. Unpublished technical report prepared for the Buddy System Project office. Bloomington IN: Indiana Univeristy, School of Education.

Eco, U. (1976). *A theory of semiotics*. Bloomington, IN: Indiana University Press.

— (1983). *The name of the rose*. William Weaver, trans. New York: Harcourt, Brace.

— (1984). *Semiotics and the philosophy of language*. Bloomington, IN: Indiana University Press.

Edelson, Daniel & O'Neil, K. (1994). *The CoVis Collaboratory Notebook: computer support for scientific inquiry*. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA.

Flavell, J. (1976). Metacognitive aspects of problem solving. *In* L. Resnick, ed. *The nature of intelligence*. Hillsdale, NJ: Erlbaum

Fodor, J. (1980). On the impossibility of acquiring more "powerful structures." *In* M. Piattelli-Palmerini, ed. *Language and learning: the debate between Jean Piaget and Noam Chomsky*, 142–62. Cambridge, MA: Harvard University Press.

Forman, E., Minick, N. & Stone, C., eds. (1993). *Contexts for learning*. New York: Oxford University Press.

Fosnot, C.T. (1989). *Enquiring teachers enquiring learners. a constructivist approach to teaching*. New York: Teacher's College Press.

Freire, P. (1993). *The pedagogy of the oppressed* (rev. ed.) New York: Continuum.

Froiland, P. (1994). Action learning: taming real problems in real time. *Training 37*, 27–33.

Gardner, H. (1993). *Frames of mind: the theory of multiple intelligences*. New York: Basic Books.

Gardner, J. (1985). *The mind's new science*. New York: Basic Books.

Gifford, B. & O'Connor, M., eds. (1992). Changing assessments: alternative views of aptitude, achievement and instruction. Boston: Kluwer.

Goforth, D. (1994). Learner control = decision making + information. *Journal of Educational Computing Research 11*, 1–26.

Greenwood, G. & Parkay, F.W. (1989). *Case studies for teacher decision making*. New York: Random House.

Griffin, P. & Cole, M. (1984). Current activity for the future: the zo-ped. *In* B. Rogoff & J. Wertsch, eds. *Children's learning in the zone of proximal development*. San Francisco: Jossey-Bass.

Hanley, J.P., Whitla, D.K., Moo, E.W. & Walter, A.S. (1970). *Curiosity/competence/community: an evaluation of man: a course of study*. Cambridge, MA: Educational Development Center.

Harasim, Linda (1993). Collaborating in cyberspace: using computer conferences as a group learning environment. *Interactive Learning Environments 3*, 119–30.

Hawkes, T. (1977). *Structuralism and semiotics*. Berkeley, CA: University of California Press.

Hay, K.E. (1994). *Towards the learner-centered design paradigm: powerful tools for investigating weather within the Children's Museum*. Unpublished paper. Indianapolis, IN: Indiana University, School of Education.

Heinich, R., Molenda, M. & Russell, J. (1993). *Instructional media and the new technology of learning*, 4th ed. New York: Macmillan.

Honebein, P., Duffy, Thomas M. & Fishman, B. (1993). Constructivism and the design of learning environments: context and authentic activities for learning. *In* Thomas M. Duffy, Joost Lowyck & David Jonassen, eds. *Designing environments for constructivist learning*. Heidelberg: Springer.

Hubbard Welsh, L., Iatridis, P., Ficklin, F. & Vaughn, S. (1994, Oct.). The first four years of implementing a problem-based curriculum: an evaluation. Paper presented at the 33d annual meeting of the Research in Medical Education Conference, Boston, MA.

Hutchins, E. (1991). The social organization of distributed cognition. *In* L. Resnick, J. Levine & S. Teasley, eds. *Perspectives on socially shared cognition.* Washington, DC: American Psychological Association.

Hlynka, D. & Belland, J. (1991). *Paradigms regained.* Englewood Cliffs, NJ: Educational Technology.

Johnson, D.W. & Johnson, R.T. (1990). Cooperative learning and achievement. *In* S. Sharan, ed. *Cooperative learning: theory and practice.* New York: Praeger.

Johnson, M. (1987). *The body in the mind.* Chicago, IL: University of Chicago Press.

Kang, I. (1995). *Constructivist principles and the design of instruction: a case study of an associate instructor training program.* Unpublished doctoral dissertation. Bloomington, IN: School of Education, Indiana University.

Katz, L.G. & Chard, S.C. (1989). *Engaging children's minds: the project approach.* Norwood, NJ: Ablex.

Kliebard, H. (1986). *The struggle for the American curriculum: 1893-1958.* Boston, MA: Routledge.

Knuth, R. (1992). *Hypermedia and learning: the case of Intermedia.* Unpublished doctoral dissertation, Bloomington, IN: Indiana University.

Kuhn, T. (1970). *The structure of scientific revolutions*, 2d ed. Chicago, IL: University of Chicago Press.

Lakoff, G. (1987). *Women, fire and dangerous things.* Chicago, IL: University of Chicago Press.

— & Johnson, M. (1980). *Metaphors we live by.* Chicago, IL: University of Chicago Press.

Landow, G. (1989a). Course assignments in hypertext: the example of Intermedia. *Journal of Research on Computing in Education 21*, 340–65.

Landow, G. (1989b). Hypertext in literary education, criticism, and scholarship. *Computers and the Humanities 23*, 173–98.

— (1992). *Hypertext: the convergence of contemporary critical theory and technology.* Baltimore, MD: Johns Hopkins University Press.

Lave, J. & Wenger, E. (1991). *Situated learning.* New York: Cambridge University Press.

Lemke, J, (1990). *Talking science: language, learning and values.* New York: Ablex.

— (1994). Semiotics and the deconstruction of conceptual learning. *Journal of Accelerative Learning and Teaching 19*, 67–110.

Linn, R., Baker, E. & Dunbar, S. (1990). Performance based assessment: expectations and validation criteria. *Educational Researcher 20*, 15–21.

Mabry, L. & Stake, R. (1994). Aligning measurement with education. *Educational Researcher 23*, 33–34.

Malcom, N. (1986). *Wittgenstein: nothing is hidden.* Cambridge, MA: Blackwell.

Marshall, H. (1988). Work or learning: implications of classroom metaphors. *Educational Researcher 17*, 9–16.

Maturana, H.R. & Varela (1992). *The tree of knowledge: the biological roots of human understanding.* Boston, MA: Shambhala.

McDermott, D. (1980). Profile of Ray Birdwhistell. *The Kinesis Report 2*, 1–16.

Merseth, K.K. & Lacey, A. (1993). Weaving a stronger fabric: the pedagogical promise of hypermedia and case methods of teacher education. *Teacher and Teacher Education 9*, 283–99.

Messick, S. (1989). Validity. *In* R. Linn, ed. *Educational Measurement*, 3d ed. New York: Macmillan.

Milheim, W. & Martin, B. (1991). Theoretical basis for the use of learner control: three different perspectives. *Journal of Computer Based Instruction 18*, 99–105.

Milter, R.G. & Stinson, J.E. (1993). Educating leaders for the new competitive environment. *In* G. Gijselaers, S. Tempelaar, S. Keizer, eds. *Educational innovation in economics and business administration: the case of problem-based learning.* London: Kluwer.

Moll, L., ed. (1990). *Vygotsky and education.* New York: Cambridge University Press.

Morris, C. (1946). *Signs, language and behavior.* New York: Prentice Hall.

National Council of Teachers of Mathematics (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: Author.

— (1991). *Professional standards for teaching mathematics.* Reston, VA: Author.

Newell, A. & Simon, H. (1972). *Human problem solving.* Englewood Cliffs, NJ: Prentice Hall.

Newman, D., Griffin, P. & Cole, M. (1989). *The construction zone: working for cognitive change in school.* New York: Cambridge University Press.

Nowakoski, A. (1994) Reengineering education at Andersen Consulting. *Educational Technology 34*, 3–8.

Page, Marilyn (1990). *Action learning: historical and contemporary perspectives.* Unpublished doctoral paper, Amherst, MA: University of Massachusetts (Eric: ED 338389).

Palinscar, A. & Brown, A. (1984). Reciprocal teaching of comprehension fostering and comprehension monitoring. *Cognition and Instruction 1*, 117–75.

Pea, Roy (1985). Beyond amplification: using the computer to reorganize mental functioning. *Educational Psychologist 20*, 167–82.

Perry, W. (1970). *Forms of intellectual and ethical development in the college years: a scheme.* New York: Holt.

Piaget, Jean (1977). *The development of thought: equilibration of cognitive structures.* New York: Viking.

Psotka, J. Massey, L.D. & Mutter, S. (1988). *Intelligent tutoring systems: lessons learned.* Hillsdale, NJ: Erlbaum.

Rasmussen, J., Brehmer, B. & Leplat, J., eds. (1991). *Distributed decision making: cognitive models for cooperative work.* Chichester: Wiley.

Resnick, L. Learning in school and out. *Educational Research 16*, 13–20.

—, Levine, J. & Teasley, S., eds. (1991). *Perspectives on socially shared cognition.* Washington, DC: American Psychological Association.

Rochelle, J. (1992). *Reflections on Dewey and technology for situated learning.* Paper presented at annual meeting of the American Educational Research Association, San Francisco, CA.

Rogoff, B. (1990). *Apprenticeship in thinking.* New York: Oxford University Press.

— (1994). Developing understanding of the idea of communities of learners. *Mind, Culture and Activity 1*, 209–29.

Rorty, Richard (1991). Objectivity, relativism, and truth: philosophical papers, Vol. 1. Cambridge, MA: Cambridge University Press.

Ross, S. & Morrison, G. (1989). In search of a happy medium in instructional technology research: issues concerning external validity, media replications, and learner control. *Educational Technology Research and Development 37*, 19–33.

Roup, R. (1993). *LabNet: toward a community of practice.* Hillsdale, NJ: Erlbaum.

Rousseau, J. (1955). *Emile.* New York: Dutton (original work published 1762).

Rumelhart, D. & McClelland, J. (1986). *Parallel distributed processing.* Cambridge, MA: MIT Press.

Salomon, G., ed. (1993). *Distributed cognitions.* New York: Cambridge University Press.

Salomon, G., Perkins, D. & Globerson, T. (1991). Partners in cognition: extending human intelligence with intelligent technologies. *Educational Research 20*, 2–9.

Savery, J. & Duffy, T. (1995). Problem based learning: an instructional model and its constructivist framework. *Educational Technology.*

Saxe, G. (1992). Studying children's learning in context: problems and prospects. *Journal of the Learning Sciences 2*, 215–34.

Scardamalia, M. & Bereiter, C. (1991). Higher levels of agency for children in knowledge building: a challenge for the design of new knowledge media. *The Journal of the Learning Sciences 1*, 37–68.

—, —, Brett, C., Burtis, P.J., Calhoun & Lea, N.S. (1992). Educational applications of a networked communal database. *Interactive Learning Environments 2*, 45–71.

Schleper, D. (1993) I lost control (and my students found it.) *Perspectives in Education and Deafness 11*, 12–15 .

Schon, D.A. (1987). *Educating the reflective practitioner.* San Francisco, CA: Jossey-Bass.

Schoenfeld, A. (1991). On mathematics and sense making: an informal attack on the unfortunate divorce of formal and informal mathematics. *In* J.F. Voss, D. Perkins & J. Segal, eds. *Informal reasoning and education.* Hillsdale, NJ: Erlbaum.

Schwen, T., Goodrum, D. & Dorsey, L. On the design of an enriched learning and information environment (ELIE). *Educational Technology 31*, 5–9.

Shank, G.D. (1987) Abductive strategies in educational research. *The American Journal of Semiotics 5*, 275–90.

Sharan, Y. & Sharan, S. (1992). *Expanding cooperative learning through group investigation.* New York: Teachers College Press.

Shavelson, R., Baxter, G. & Pine, P. (1992). Performance assessments: political rhetoric and measurement reality. *Educational Researcher 4*, 22–27.

Skinner, B. (1968). *The technology of teaching.* New York: Appelton-Century-Crofts.

— (1984). The shame of American education. *American Psychologist 39*, 947–54.

Slavin, R. (1990). *Cooperative learning: theory, research and practice.* Boston, MA: Allyn & Bacon.

Soloway, E., Guzdial, M. & Hay, K.E. (1994). Learner-centered design: the challenge for HCI in the 21st century. *Interactions 1*, 36–48.

Spizizen, G. & Hart, C. (1985). Active learning and the case method: theory and practice. *Cornell Hotel and Restaurant Administration Quarterly, 26*, 63–633.

Sternberg, R. (1987). Teaching intelligence: the application of cognitive psychology to the improvement of intellectual skills. *In* J. Baron & R. Sternberg, eds. *Teaching thinking skills.* New York: Freeman.

Stevens, R. (1983). *Law school: legal education in America from the 1830's to the 1980's.* Chapel Hill, NC: University of North Carolina Press.

Stinson, J.E. (1994). *Can digital equipment survive?* Paper presented at the 6th International Conference on Thinking, Boston, MA.

Suchman, L.A. (1987). *Plans and situated actions.* New York: Cambridge University Press.

Sykes, G. & Bird, T. (1992). Teacher education and the case idea. *In* G. Grant, ed. *Review of research in education*, Vol. 18. Washington, DC: American Educational Research Association.

Tharp, R. & Gallimore, R. (1988). *Rousing minds to life.* New York: Cambridge University Press.

Van der Veer, R. & Valsiner, J. (1991). *Understanding Vygotsky.* Cambridge, MA: Blackwell.

von Glasersfeld, E. (1984). An introduction to radical constructivism. *In* P. Watzlawick, ed. *The invented reality*, 17–40. New York: Norton.

— (1989). Cognition, construction of knowledge, and teaching. *Synthese 80*, 121–40.

— (1992). Constructivism reconstructed: a reply to Suchting. *Science and Education 1*, 379–84.

von Uexkull, J. (1957). A stroll through the worlds of animals and men. *In* C. Schiller, ed. *Instinctive behavior: the development of a modern concept.* New York: International Universities Press.

Vygotsky, L. (1962). *Thought and language.* Cambridge, MA: MIT Press.

— (1978). *Mind in society.* Cambridge, MA: Harvard University Press.

— (1981) The instrumental method in psychology. *In* J. Wertsch, ed. *The concept of activity in Soviet psychology.* Armouk, NY: Sharpe.

Wasserman, S. (1993). *Getting down to cases.* New York: Teachers College Press.

Wellman, H. (1990). *The child's theory of mind.* Cambridge, MA: MIT Press.

Wells, G. & Chang-Wells, G. (1992). *Constructing knowledge together.* Portsmouth, NH: Heinemann.

Wertsch, J. (1985). *Vygotsky and the social formation of mind.* Cambridge MA: Harvard University Press.

Wertsch, J. (1991). *Voices of the mind: a sociocultural approach to mediated action.* Cambridge, MA: Harvard University Press.

Wertsch, J. (1994). The primacy of mediated action in sociocultural studies. *Mind, Culture, and Activity 1*, 202–08.

Whitehead, Alfred North (1929). *The aims of education and other essays.* New York: Free Press.

Williams, S.M. (1992). Putting case-based instruction into context: examples from legal and medical education. *Journal of the Learning Sciences 2*, 367–427.