23. RICH ENVIRONMENTS FOR ACTIVE LEARNING

R. Scott Grabinger
UNIVERSITY OF COLORADO AT DENVER

23.1 CHAPTER PURPOSES

In today's complex world, simply knowing how to use tools and knowledge in a single domain is not enough to remain competitive. People must also learn when to use tools and knowledge in new domains and different situations. Industry specialists report that people at every organizational level must be creative and flexible problem solvers (Lynton, 1989). Even members of the "blue-collar" workforce must demonstrate advanced levels of problem-solving skills to attain and retain employment. This requires the ability to apply experience and knowledge to address novel problems. Consequently, learning to think critically, to analyze and synthesize information to solve technical, social, economic, political, and scientific problems, and to work productively in groups are crucial skills for successful and fulfilling participation in our modern, competitive society.

This chapter has two main goals: First, I describe and organize the common elements of rich environments for active learning, or REALs, including the theoretical foundations and instructional strategies to provide a common ground for discussion. REALs are based on constructivist values and theories including "collaboration, personal autonomy, generativity, reflectivity, active engagement, personal relevance, and pluralism" (Lebow, 1993, p. 5). REALs provide learning activities that, instead of transferring knowledge to students, engage students in a continuous collaborative process of building and reshaping understanding as a natural consequence of their experiences and interactions with the world in authentic ways (Forman & Pufall, 1988; Fosnot, 1989; Goodman, 1984). Advocating a holistic approach to education, REALs reflect the assumption that the process of knowledge and understanding acquisition is "firmly embedded in the social and emotional context in which learning takes place" (Lebow, 1993, p. 6), Second, I look at some of the research conducted with various implementations of REALs. I examine the research methodologies used, the topics investigated, and close with suggestions for future research directions.

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23.2 NEED FOR EDUCATIONAL CHANGE

23.2.1 Changing Society

Education is receiving increasing pressure from changing global economic circumstances and complex societal needs. Yet, according to Lynton (1989, p. 23), "At this time . . . education is far from fully contributing to the economic well-being of this country" [United States]. Public and private institutions are demanding employees who can think critically and solve a range of problems, yet they claim that those people are difficult to find.

Education, to its credit, is neither deaf to the plea nor ignorant of the need. Calls for restructuring the way students learn come from a variety of institutions including the American Association for the Advancement of Science (1989) and the National Council of Teachers for Mathematics (1989). Educators agree that we must help students learn to solve problems and think independently (Bransford, Sherwood, Hasselbring, Kinzer & Williams, 1990; Feuerstein, 1979; Linn, 1986; Mann, 1979; Resnick & Klopfer, 1989; Segal, Chipman & Glaser, 1985). The challenge for educators is to develop strategies that teach content in ways that also teach thinking and problem-solving skills (Bransford et al., 1990).

22.2.2 Weaknesses within the Current System

There is considerable evidence that today's students are not particularly strong in the areas of thinking and reasoning (Bransford, Goldman & Vye, 1991; Nickerson, 1988; Resnick, 1987). Bransford (1990, pp. 115–16) states that the "basic problem is that traditional instruction often fails to produce the kinds of transfer to new problem-solving situations that most educators would like to see." Neither do children often experience in the classroom the kinds of problems that make knowledge relevant to them (Collins, Brown & Holum, 1991). "They [students] treat knowledge as ends rather than as a means to important ends" (Bransford et al., 1990, p. 117). Students treat new information as facts to be memorized and recited back rather than as tools to solve problems relevant to their own needs.

23.2.2.1. Inert Knowledge. Research shows that knowledge learned but not explicitly related to relevant problem solving remains inert (CTGV, 1993c; Perfetto, Bransford & Franks, 1983; Whitehead, 1929). Knowledge acquired in abstract circumstances without direct relevance to the needs of learners is not readily available for application or transfer to novel situations (for a review of transfer research, refer to Butterfield & Nelson, 1989; Clark & Voogel, 1985). The Cognition and Technology Group at Vanderbilt (CTGV) (CTGV, 1993c) specifies the following flaws in our conventional approaches to schooling and teaching that lead to inert knowledge:

1. In the constant battle of breadth versus depth, breadth usually always wins. We (educators) tend to fill our students with facts and leave no time for dealing with topics in depth. "Students who rely on memorized algorithms for solving problems typically do not perform as well on transfer problems as do students who rely on an understanding of the underlying concepts" (Robertson, 1990, p. 253).
2. In our desire to cover as much material as possible, we focus our instructional activities on abstract decontextualized basic skills, concepts, and technical definitions that we believe have broad applicability and that are unaffected by the activities or environments in which they are acquired and used (Brown, Collins & Duguid, 1989). However, when we do this, students do not learn when to apply those skills or within what kinds of contexts they work. We do this despite a large body of evidence that indicates that abstracted skills are seldom transferred from one domain to another (Butterfield & Nelson, 1989; Clark & Voogel, 1985).
3. When we do provide practice for our students, we give them arbitrary, uninteresting, unrealistic problems to solve. The example of story problems in math is overused. We can also find examples of oversimplified, unrealistic problems in the sciences, language arts, and social studies. Again, we do this in the mistaken belief that we must emphasize decontextualized skills that are applicable everywhere.
4. We treat students passively for 12 to 16 years, rarely giving them the opportunity to take responsibility for their own learning, to explore ideas of their own choosing, to collaborate with one another or with teachers, or to make valuable contributions to the learning of others. They do not learn to take charge of their own learning, nor do they learn the skills necessary to become lifelong learners and daily problem solvers.

I add a couple of more items not cited in the CTGV article to the list of conventional educational practices:

5. Students are not evaluated in authentic ways. After teaching in decontextualized ways, we test in the same ways. We do not look at actual performance but use complex paper-pencil tests to measure the quantity of knowledge learned.
6. Finally, our current school practices often have negative effects on the morale and motivation of students. Perelman (1992, p. 72) states that "Students are forced to compete to achieve as much as they can within the periods of time allotted for each activity. This design requires that most students fail or do less well most of the times so that a minority of them can be labeled 'excellent.' The main functional focus of the system is not 'learning,' it is 'screening out' "(p. 72).

We have created an evaluation, testing, and grading substructure that helps perpetuate the system. Education is often a "game" that teaches our students to focus on tests and grades rather than on problem solving in a risk-free environment. The best students learn early on that they succeed best by working by themselves as quickly as possible. They learn to "beat" the tests.

23.2.2.2. Erroneous Assumptions. We begin to change these conventional practices by calling into question some of our basic assumptions. Berryman (1991) says that the educational practices described above stem from five erroneous assumptions about learning that have governed education since the beginning of the industrial age. He holds that we often assume incorrectly that:

1. People easily transfer learning from one situation to another if they have learned the fundamental skills and concepts.
2. Learners are "receivers" of knowledge in verbal forms from books, experts, and teachers.
3. Learning is entirely behavioristic, involving the strengthening of bonds between stimuli and correct responses (see 2.2).
4. Learners are blank slates ready to be written on and filled with knowledge.
5. Skills and knowledge are best acquired independent of realistic contexts for use.

To begin to address the issues of transfer and instructional methods to meet employer and societal needs, reasoning and problem-solving skill development must be an integrated part of an interdisciplinary program of study in education (Lynton & Elman, 1987), a program or environment that places students in situations where they can practice solving problems in a meaningful and constructive manner.

23.2.3 We Need to Look at Other Ways

One view of an alternative framework comes from researchers who are beginning to emphasize the importance of anchoring or situating instruction in meaningful problem-solving environments . . . (CTGV, 1993c, p. 81).

The Cognition and Technology Group at Vanderbilt (1993c) is a leader in describing alternative frameworks of instruction and schooling. The group posits the following necessary changes: first, we as educators must establish *new goals for learning.* We must move from emphasizing decontextualized reading and computational skills to developing independent thinkers and learners who engage in lifelong learning. This does not mean that we abandon the important skills of reading and computation; instead, we should be teaching reading and computation within more situated contexts that demonstrate the value of those skills.

Second, in contrast to our long operative conventional assumptions (see above), we must base our teaching on *new assumptions about the nature of thinking, learning, and instruction.* We must accept that:

> . . . the mere accumulation of factual or declarative knowledge is not sufficient to support problem solving. In addition to factual or declarative knowledge, students must learn why, when, and how various skills and concepts are relevant (CTGV, 1993c, p. 79).

Effective problem solving and thinking are not based solely on motivation and knowledge of thinking strategies but also on well-organized and indexed content knowledge. Learners must have rich knowledge structures with many contextual links to help them persevere with complex problems. Therefore, to compare new assumptions about learning with the aforementioned old assumptions, we propose the following changes (see also Table 23-1 for a summary):

1. People transfer learning from one like situation to another with difficulty. Learning is more likely to be transferred from complex and rich learning situations. Learning activities must help students think deeply about the content in relevant and realistic contexts (CTGV, 1993c).
2. Learners are "constructors" of knowledge in a variety of forms and from peers in addition to experts and teachers. They take an active role in forming new understandings and are not just passive receptors.
3. Learning is cognitive and involves the processing of information and the constant evolution and creation of knowledge structures. We must focus on and make visible thinking and reasoning processes as well as content. We are not suggesting abandoning the teaching of content to teach only thinking and reasoning, because "knowledge of concepts, theories, and principles empowers people to think effectively" (Bransford et al., 1990, p. 115). (See Chapter 5 for a more extensive discussion of cognitions and Chapter 21 for a discussion of cognitive learning models.)
4. Learners bring their own needs and experiences to a learning situation and are ready to act according to those needs. We must incorporate those needs and experiences into instructional strategies to help students take ownership and responsibility for their own learning.
5. Skills and knowledge are best acquired within realistic contexts. Morris (1979) calls this *transfer appropriate processing.* Transfer appropriate processing means that students must have the opportunity to practice and learn the outcomes that are expected of them under realistic or authentic conditions.
6. Assessment of students must take more realistic and holistic forms utilizing projects and portfolios and deemphasizing standardized testing. Educators are increasingly aware that conventional achievement and intelligence tests do not measure the ability of people to perform in everyday settings and adapt to new situations (CTGV, 1993c).

A discussion of the foundations for these assumptions, their implementation, and research issues makes up the rest of this chapter.

TABLE 23-1. OLD VERSUS NEW ASSUMPTIONS ABOUT LEARNING

Old Assumptions	New Assumptions
1. People transfer learning with ease by learning abstract and decontextualized concepts.	1. People transfer learning with difficulty, needing both content and context learning.
2. Learners are receivers of knowledge.	2. Learners are active constructors of knowledge.
3. Learning is behavioristic and involves the strengthening of stimulus and response.	3. Learning is cognitive and in a constant state of growth and evolution.
4. Learners are blank slates ready to be filled with knowledge.	4. Learners bring their own needs and experiences to learning situations.
5. Skills and knowledge are best acquired independent of context.	5. Skills and knowledge are best acquired within realistic contexts.
	6. Assessment must take more realistic and holistic forms.

23.3 RICH ENVIRONMENTS FOR ACTIVE LEARNING

23.3.1. Definition of REALs

We must implement a number of strategies to adopt the new assumptions about thinking, learning, instruction, and achievement. The adoption of these strategies creates learning environments that we call *rich environments for active learning* (REALs), which are comprehensive instructional systems that:

- Are evolving from constructivist philosophies and theories
- Promote study and investigation within authentic (i.e., realistic, meaningful, relevant, complex, and information-rich) contexts
- Encourage the growth of student responsibility, initiative, decision making, and intentional learning
- Cultivate an atmosphere of cooperative learning among students and teachers
- Utilize dynamic, generative learning activities that promote high-level thinking processes (i.e., analysis, synthesis, problem solving, experimentation, creativity, and examination of topics from multiple perspectives) to help students integrate new knowledge with old knowledge and thereby create rich and complex knowledge structures
- Assess student progress in content and learning to learn through realistic tasks and performances

It is important to note that two of the most critical features of learning environments are integration and comprehensiveness (Hannafin, 1992). Hannafin describes *integration* as a process of linking new knowledge to old and modifying and enriching existing knowledge. Integration enhances the depth of learning to increase the number of access points to that information. Goldman states that

> These environments are designed to invite the kinds of thinking that help students develop *general* skills and attitudes that contribute to effective problem solving, plus acquire *specific* concepts and principles that allow them to think effectively about particular domains (Goldman et al., 1992, p. 1).

Comprehensiveness refers to the importance of linking learning in broad, realistic contexts rather than decontextualizing and compartmentalizing knowledge. REAL learning strategies, then, guide and mediate an individual's learning and support the learner's decision making (Hannafin, 1992). Themes are used to help organize learning around contexts that focus on problem solving or projects that link concepts and knowledge to focused activities within the environment (Hannafin, 1992).

23.3.1.1. What a REAL Isn't. Because the term *learning environment* is broadly and carelessly used in educational literature to describe everything from schools to classrooms to computer microworlds to learning activities to air conditioning and furniture, I'll try to clarify what a REAL isn't before examining the attributes in more detail. I attempt to make the case that a REAL is a more accurate description of what people generally mean when they use *learning environment.*

First, a REAL is not a delivery technology like video, CD-ROM, or audiotapes. Clark (1994) defines *delivery technologies* as those that draw on resources and media to deliver instruction and affect the cost and access of instruction. Media technologies can be integral components of REALs. However, a REAL is not limited to any specific media but instead is an assortment of methods and ideas that help cause learning. Clark's point is important from a research standpoint because instructional methods are often confounded with media in research, and he argues strongly and convincingly that it is instructional methods, not media, that influence learning. He contends that any necessary teaching method can usually be designed in more than one media. Although there are varying degrees of acceptance and disagreement with Clark's point of view (e.g., Jonassen, 1994b; Kozma, 1994), a REAL is a set of instructional methods designed on the assumptions that media are tools for students and teachers to use and that the learning that occurs within the environment is founded on the activities and processes that encourage thinking and reasoning, not the media that deliver information.

Second, do not confuse REALs with computer-based microworlds or learner support environments (LSEs) (Allinson & Hammond, 1990). Computer-based microworlds are computer programs that are designed to apply constructivist theories. Examples include case-based applications, simulations, intentional learning environments, and some hypermedia resources. Developers of microworlds often refer to their programs as learning environments because they often attempt to simulate on a smaller simplified scale realistic environments. However, I contend that this limits the concept of learning environment. Learning environments, and especially REALs, are much more comprehensive and holistic than individual computer applications. Although some computer-based applications use constructivist ideas quite admirably [see especially the *Strategic Teaching Framework* (Duffy, 1992; Duffy, 1996)] and the *Transfusion Medicine Modules* (Ambruso & The Transfusion Medicine Group, 1994), they are not learning environments in the sense that REALs are. To create REALs, teachers must involve their students, parents, administrators, and colleagues in planning and implementing strategies that encourage student responsibility, active knowledge construction, and generative learning activities on a large scale and in a variety of methods and forms. Microworlds may play a role in a REAL through the delivery of information, practice, finding and presenting information, stimulation of high-level thought processes, promotion of collaboration, or exploration. However, REALs involve many more activities and demand much more flexibility than can probably ever be contained in a single computer program. A REAL is an environment that "includes the content taught, the pedagogical methods employed, the sequencing of learning activities, and the sociology of learning" (Collins et al., 1991, p. 6).

Therefore, what are the critical attributes of REALs? The next section of this chapter discusses each of the main attributes in its definition: (a) the application of constructivist ideas, (b) authentic, generative learning activities, (c) student responsibility and initiative, (d) collaboration, (e) higher-level thinking skills and metacognition, and (f) authentic assessment strategies. I will illustrate each attribute with examples of functioning REALs from the areas of anchored instruction, problem-based learning (PBL), case-based learning, reciprocal teaching, and teacher education.

23.4 THE MAIN ATTRIBUTES OF REALS

23.4.1 Constructivist Influences

23.4.1.1. Historical Antecedents. REALs (i.e., constructivist learning environments, information-rich learning environments, or interactive learning environments) are not new to education. We can go back to Socrates (470–390 BC) and see that he used problems and questions to guide students to analyze and think about their environments (Coltrane, 1993). Rousseau prescribed using direct experience (Farnham-Diggory, 1992). In the early 1900s, John Dewey (1910) proposed student-directed reforms and experiential learning. Bruner (1961) advocated discovery or inquiry learning around realistic problems. The notion that students should learn through practice, application, and apprenticeship has been with us for centuries. It wasn't until the industrial age, when we needed places to store children until old enough to work on assembly lines, that we began trying to mass produce replicable results. Yet, the last 5 to 10 years have seen renewed emphasis on reforming schools and teaching practices to replace our production lines with classrooms that teach people to think and to solve problems. This current effort at renewal revolves around a set of ideas and theories referred to as *constructivism.*

23.4.1.2. Characteristics of Constructivism. The class of theories that guides the development of REALs is called *constructivist theories* (see 7.3; Bednar, Cunningham, Duffy & Perry, 1991; Bransford & Vye, 1989; Clement, 1982; Duffy & Bednar, 1991; Minstrell, 1989; Perkins, 1991; Resnick & Klopfer, 1989; Scardamalia & Bereiter, 1991; Schoenfeld, 1989; Spiro, Feltovich, Jacobson & Coulson, 1991). I shall, for background, provide only a brief description. Fundamentally, constructivism asserts that we learn through a continual process of constructing, interpreting, and modifying our own representations of reality based on our experiences with reality (Jonassen, 1994c). Learning includes a social component and conceptual growth comes from sharing perspectives and modifying our internal representations in response to that sharing (Bednar et al., 1991). Wheatley (1992) summarizes these ideas and emphasizes the importance of active involvement in the environment:

> Learning (innovation) is fostered by information gathered from new connections; from insights gained by journeys into other disciplines or places; from active, collegial networks and fluid, open boundaries. Learning (innovation) arises from ongoing circles of exchange where information is not just accumulated or stored but created. Knowledge is generated anew from connections that weren't there before. When this information self-organizes, learning (innovation) occurs, the progeny of information-rich, ambiguous environments (p. 113).

There are several important characteristics of the constructivist view of learning that govern our design of REALs. First is the notion that knowledge is not a product to be accumulated but an active process in which the learner attempts to make sense out of the world (Gurney, 1989) that is under constant evolution. Brown, Collins, and Duguid (1989) illustrate this idea:

> A concept, for example, will continually evolve with each new occasion of use, because new situations, negotiations, and activities inevitably recast it in a new, more densely textured form. So a concept, like the meaning of a word, is always under construction (Brown et al., 1989, p. 33).

A second characteristic is the notion that people conditionalize their knowledge in personal ways (Gurney, 1989). That is, they acquire knowledge in forms that enable them to use that knowledge later (Bransford et al., 1990). Bransford (1990, p. 122) states that ". . . there are large differences between knowing something and spontaneously thinking to do it or use it when one is engaged in an actual problem-solving situation." Knowledge is "indexed" to the contexts in which we encounter it. We are unlikely to use knowledge that is decontextualized because it has no relevance for us. A person who indexes and conditionalizes knowledge knows when to apply that knowledge. A person who learns in a decontextualized way often is not aware that he or she has the applicable knowledge to solve a problem. Students must acquire concepts and theories in ways that help them use the information later on and appreciate the value of that information. Brown, Collins, and Duguid (1989, p. 36) describe this process as "indexicalizing knowledge." They mean that rich involvement in realistic and relevant problem solving enables learners to develop many broad and deep indexicalized representations that enable them to apply more spontaneously knowledge to new situations because they can compare a known and relevant situation with a new situation. The more links there are across related knowledge structures, the more likely students are to apply that knowledge. The more closely the learning context resembles the actual context, the better people will perform. Tulving and Thompson (1973) refer to this as *encoding specificity,* which holds that successful retrieval of information is enhanced when cues relevant to later retrieval of that information are encoded along with the material learned. It is important to note that constructivists contend that these rich links cannot be developed in decontextualized learning activities; rather learning must be placed in realistic contexts that provide cognitive conflict or puzzlement and determine the organization and nature of what is learned (Savery & Duffy, 1994).

White (cf. Robertson, 1990) theorizes that there are two kinds of links that need to be developed while learning: internal and external. Internal associations are connections among the criterial attributes of a principle. Internal associations reflect the learner's understanding of the concept. External associations refer to connections between the principle and everyday experiences or context and indicate the "usability" of a concept. Learning to solve problems requires both kinds of links. Our schools are good at building the internal links, but poor at providing the external links.

The third major characteristic of constructivism is the importance of collaboration and the social negotiation of meaning. Common understandings and shared meanings are developed through interaction among peers and teachers. This is the cultural aspect of knowledge.

> The activities of a domain are framed by its culture. Their meaning and purpose are socially constructed through negotiations among present and past members. Activities thus cohere in a way that is, in theory, if not always in practice, accessible to members who move within the social framework. These coherent, meaningful, and purposeful activities are authentic, according to the definition of the term we use here (Brown et al., 1989, p. 34).

This social aspect of constructivism is important on an individual level as well as cultural level, for collaborative interactions allow us to test the viability of our understandings, theories, and conjectures (Savery & Duffy, 1994).

23.4.1.3. REAL Example: Cognitive Flexibility Theory. Cognitive flexibility theory (CFT) implements many of the ideas of constructivism (Jacobson & Spiro, 1992; Spiro et al., 1991), particularly focusing on the development of conditionalized and indexicalized knowledge structures.

> Essentially, the theory states that cognitive flexibility is needed in order to construct an ensemble of conceptual and case representations necessary to understand a particular problem-solving situation. The idea is that we cannot be said to have a full understanding of a domain unless we have the opportunity to see different case representations (Borsook & Higginbotham-Wheat, 1992, p. 63).

CFT attempts to teach content in ill-structured domains, that is, in domains where the knowledge base is so vast and complex that multiple solutions to problems are possible and likely. There are no clear-cut answers in ill-structured domains, so simple algorithms often fail. Ill-structured domains include law, medicine, and education. Therefore, CFT emphasizes the following instructional strategies to help learners develop rich and deep knowledge structures (Jacobson, 1994):

1. CFT uses several cases and rich examples in their full complexity. One of the tenets of CFT is to avoid oversimplifying knowledge and examples because it leads to future misunderstandings that are difficult to change.
2. CFT uses multiple forms of knowledge representation, providing examples in several kinds of media. CFT encourages students to look at knowledge in several ways and from several perspectives.
3. CFT links abstract concepts to case examples and brings out the generalizable concepts and strategies applicable to other problems or cases.
4. To avoid the mistakes of oversimplification, CFT presents a number of examples to make apparent, rather than hide, the variability of concepts and themes within the domain.

Although CFT does not emphasize the collaborative nature of knowledge construction, its strategies include opportunities for social negotiation of meaning. We examine further on in the chapter other examples of REALs that place a high emphasis on cooperative learning.

23.4.2 Authentic Learning Contexts

The second characteristic of a REAL is that learning takes place within an authentic context. An authentic task, activity, or goal provides learning experiences as realistic as possible given the age and maturation level of the students and other environmental constraints, including safety and expense. The most important feature of this definition is to understand that "realistic experience" includes more than the situation; it includes both the context and the tasks that a learner performs (Honebein, Duffy & Fishman, 1993). *Those tasks must be realistic in terms of the cognitive, physical, and social requirements.* A realistic context includes as much fidelity as possible to what students will encounter outside school in terms of tools, complexity, and interactions with people (Williams & Dodge, 1992).

Authenticity is important to REALs for three reasons. First, it encourages students to take ownership of the situation and their own learning. Realistic problems hold more relevance to students needs and experiences, because they can relate what they are learning to problems and goals that they see every day. Second, it develops deeper and richer (indexicalized and conditioned) knowledge structures leading to a higher likelihood of transfer to novel situations. Finally, it encourages collaboration and negotiation. Complex problems require a team approach that provides natural opportunities for learners to test and refine their ideas and to help each other understand the content.

23.4.2.1. REAL Example: Anchored Instruction. One of the ways to create authentic instruction in a REAL is to anchor that instruction on a realistic event, problem, or theme (CTGV, 1990, 1992a, 1992b, 1993a, 1993d). Anchored instruction is fixed within a real-world event that is appealing and meaningful to students (Bransford et al., 1990). Anchored instruction involves complex contexts that require students to solve interconnected subproblems. Students share multiple perspectives, solutions, and processes (CTGV, 1992b). "At the heart of the model is an emphasis on the importance of creating an anchor or focus to generate interest and enable students to identify and solve problems and pay attention to their own perception and comprehension of these problems" (Bransford et al., 1990, p. 123).

In anchored learning situations, students develop component skills and objectives in the context of meaningful, realistic problems and problem-solving activities. These complex contexts are called *macrocontexts* (Williams & Dodge, 1992, p. 373). The primary goal of anchored instruction (and REALs) is to overcome the problem of inert knowledge. For example, students in an instructional design and development class work in teams with actual clients to develop instruction that will be delivered to another group of students. They must define the problem, identify resources, set priorities, and explore alternative solutions—the same skills and abilities that are required during realistic, outside-of-the-classroom problem-solving and decision-making activities. This is in direct contrast to the way students develop component skills and objectives in a more traditional classroom environment by working simplified, compartmentalized, and decontextualized problems. Simply stated, it is the difference between providing meaningful, authentic learning activities and "I'm never going to use this" activities.

Anchored instruction shares many features of programs that are case based and problem based (Barrows, 1985; Spiro et al., 1991; Williams & Dodge, 1992). The idea is to let learners experience the intellectual changes that experts feel when modifying their own understandings from working with realistic situations (CTGV, 1992b).

Effective anchors are intrinsically interesting, fostering ownership, and help students notice the features of problem situations that make particular actions relevant (Bransford et al., 1990, p. 123). The CTGV (1991) uses the following design principles when creating anchored instruction. First, they use a video-based presentation format because of the dramatic power of the medium and because of the use of multiple modalities, realistic imagery, and omnipresence in our culture. Second, they present a problem using actors and a narrative format for interest. Third, the problem solution requires a generative learning format in which students must identify pertinent information in the fourth feature, embedded data design. Fifth, the problem is complex with the possibility of multiple solutions and perspectives and requiring a team approach. Sixth, they use pairs of similar problems in different contexts to enrich the indexicalization of knowledge structures. Finally, they attempt to draw links across the curriculum to enhance the relevance of the problem.

There are several advantages to organizing curricula and learning around anchors and then progressing to hands-on projects (CTGV, 1993a). First, it is more practical and manageable for teachers to create anchors in the classroom than to try to arrange all of the resources, planning, and meetings around actual community-based projects. Second, the chance to work through one or more anchored problems prepares students for actual problems they may undertake at a later time. Third, anchors provide a common experience and knowledge base that helps students share information with each other and with community members.

One of the CTGV's projects in anchored instruction is the *Jasper Woodbury* series (CTGV, 1992b). Jasper is a video-based series designed to promote problem posing, problem solving, reasoning, and effective communication. Each of Jasper's adventures is a 15- to 20-minute story in which the characters encounter a problem that the students in the classroom must solve before they are allowed to see how the movie characters solved the problem. The Jasper series helps students learn to break a problem into parts, generate subgoals, find and identify relevant information, generate and test hypotheses, and cooperate with others.

23.4.3 Student Responsibility and Initiative

> Information-rich learning environments are not designed as much as assembled, informally by individual learners. Hence they are constructivist in an almost literal sense of the term (Yacci, 1994, p. 1).

The third characteristic of REALs is that they are student centered. Student-centered learning environments place a major emphasis on developing intentional learning and lifelong learning skills. These skills include the abilities for self-reflection and metacognition.

23.4.3.1. Intentional Learning. Scardamalia and her colleagues noticed that passive or immature learners have certain characteristics that prevent them from becoming skillful problem solvers (1989). First, immature learners tend to organize their mental activities around topics rather than goals, promoting decontextualization and failing to see the relevance of the activity to their lives. Second, they tend to focus on surface features and do not examine a topic in depth. Third, they work straight ahead; that is, they tend to work until a task is finished. They do not take time to examine the quality of their work, nor do they make revisions in their work or thinking. Finally, they think of learning in an additive fashion rather than transforming and enriching their existing knowledge structures.

These characteristics are, in essence, the product of the conventional kind of schooling that we described earlier in the chapter. These behaviors prevent students from transferring their knowledge to new problems because they have learned in a decontextualized context and have learned with strategies that are decontextualized. They do not see the applicability of what they learned. Palincsar (1990, p. 37) states that:

> To achieve transfer, it is necessary to attend to the context in which instruction and practice occur; transfer is likely to occur to the extent that there are common elements between the situation in which the children are learning this tactic and the situations in which such a tactic would be useful (p. 37).

Palincsar, Scardamalia, and Bereiter are leading proponents of the conviction that students must be taught to take more responsibility for their own learning to enhance the likelihood of transfer. They refer to this concept as *intentional learning,* or "those cognitive processes that have learning as a goal rather than an accidental outcome" (Bereiter & Scardamalia, 1989, p. 363). Palincsar and Klenk (1992) state that "Intentional learning, in contrast to incidental learning, is an achievement resulting from the learner's purposeful, effortful, self-regulated, and active engagement." To be intentional learners, students must learn to learn as well as learn to accrue knowledge. Learning to learn involves the teaching of generic skills as much as it does occupational or domain-specific skills. Teaching, too, takes on a revised role, for to teach for intentional learning means to cultivate those general abilities that facilitate lifelong learning (Palincsar, 1990). The main skills involved in teaching students to be more intentional are questioning, self-reflection, and metacognition, "or the awareness and ability to monitor and control one's activity as a learner" (Brown, Bransford, Ferrara & Campione, 1983, p. 212).

23.4.3.2. Questioning. Scardamalia and Bereiter (1991) believe that one of the first steps in developing intentional learners is by helping students take more executive control over what they decide to learn through the development of questioning skills. They point out that in a typical classroom, teachers ask the questions and that the question-generation and asking processes involve important high-level thinking skills and executive control decisions. Adults ask questions based on their needs, but teachers ask questions of students based on the teacher's perceptions of student needs. The students, therefore, do not ask questions related to their needs and do not learn to perform the analysis activities related to question generation. Research by Scardamalia and Bereiter (1991) indicate that students can learn to ask questions to guide their knowledge building, thus assuming a "higher level of agency" and more ownership for their learning. In a student-centered REAL, students are given more executive control over their learning to enable them to take more ownership, to find more relevance and authenticity, and to learn lifelong-learning skills.

In addition to questioning, other intentional behaviors include goal setting, managing time, and setting priorities. Each of these helps students learn to manage their own learning and become more independent in the learning process. This independence leads to more ownership as the students discover that they are able to pursue their own needs and uncover information that is important to them.

23.4.3.2. Self-Reflection. A second skill in intentional learning is self-reflection. "*Self-reflection* implies observing and putting an interpretation on one's own actions, for instance, considering one's own intentions and motives as objects of thought" (Von Wright, 1992, p. 61). Von Wright writes that self-reflection involves the abstraction of meaning and is an interpretative process aimed at the understanding of reality. To understand the world in different ways involves modifying our conceptions of the world and our place in the world. It involves thinking about reality in alternative ways.

Von Wright (1992) goes on to describe two levels of reflection. One level of reflection has to do with the ability to reflect about features of the world in the sense of considering and comparing them in mind and thinking about on ways of coping in familiar contexts. This involves learning to think about implications and consequences of actions. A second level of reflection is the ability to think about one's self as an intentional subject of one's own actions and to consider the consequences and efficacy of those actions. This involves the ability to look at one's self in an objective way and to consider ways of changing to improve performance. The second level of reflection also involves metacognitive learning skills.

23.4.3.3. Metacognitive Skills. "Metacognitive skills refer to the steps that people take to regulate and modify the progress of their cognitive activity: to learn such skills is to acquire procedures which regulate cognitive processes" (Von Wright, 1992, p. 64). Metacognitive skills include taking conscious control of learning, planning and selecting strategies, monitoring the progress of learning, correcting errors, analyzing the effectiveness of learning strategies, and changing learning behaviors and strategies when necessary (Ridley, Schutz, Glanz & Weinstein, 1992). These abilities interact with developmental maturation and domain expertise. Immature learners can't to do this; they may have learned a single strategy, such as memorization, and then attempt to apply that to all situations.

Studies show that use of metacognitive strategies can increase learning skills and that independent use of these metacognitive strategies can be gradually developed in people (Biggs, 1985; Brown, 1978; Weinstein, Goetz & Alexander, 1988). Blakely and Spence (1990) describe several basic strategies for developing metacognitive behaviors:

1. Students should be asked to identify consciously what they "know" as opposed to "what they don't know."
2. Students should keep journals or logs in which they reflect on their learning processes, thinking about what works and what doesn't.
3. Students should manage their own time and resources, including estimating time requirements, organizing materials, and scheduling the procedures necessary to complete an activity
4. Students must participate in guided self-evaluation through individual conferences and checklists to help them focus on the thinking process.

23.4.3.4. REAL Example: Reciprocal Teaching. One of the manifestations of a REAL that emphasizes the development of intentional learning skills is reciprocal teaching. The context of reciprocal teaching is social, interactive, and holistic. Palincsar and Klenk (1992) used reciprocal teaching with at-risk first-grade students to develop reading skills. Palincsar and Klenk describe reciprocal teaching as:

> . . . an instructional procedure that takes place in a collaborative learning group and features guided practice in the flexible application of four concrete strategies to the task of text comprehension: questioning, summarizing, clarifying, and predicting. The teacher and group of students take turns leading

discussions regarding the content of the text they are jointly attempting to understand (Palincsar & Klenk, 1992, p. 213).

These strategies are the kinds of intentional learning strategies that encourage self-regulation and self-monitoring behaviors.

The relationship of reciprocal teaching to REALs is founded on three theoretical principles based on the work of Vygotsky (1978) as described by Palincsar and Klenk (1992). The first principle states that the higher cognitive processes originate from social interactions. This is consistent with the constructivist theories described above. The second principle is Vygotsky's *zone of proximal development* (ZPD). Vygotsky (p. 86) described the ZPD as "the distance between the actual developmental level 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." Reciprocal teaching is designed to provide a zone of proximal development in which students, with the help of teachers and peers, take on greater responsibility for learning activities. Finally, Vygotsky's third principle advocates that learning take place in a contextualized, holistic activity that has relevance for the learners. In other words, we revisit the notion of authentic learning or anchored instruction.

How, then, does reciprocal teaching work? The process begins with a text that a class reads silently, orally, or read-along, depending on the skill level of the students. Following each segment, a dialogue leader (students take turns) asks questions that deal with content or "wonderment" issues. The questions often stimulate further inquiry. The other students respond to the questions, raise their own questions, and, in cases of disagreement or confusion, reread the text. The discussion leader is responsible for summarizing and synthesizing the reading and discussion and clarifying the purpose of the reading. The leader also generates and solicits predictions about the upcoming text to prepare for meaningful reading of the next segment. The teacher must model the appropriate behavior and provide scaffolding to sustain the discussion. (The preceding description is taken from Palincsar & Klenk, 1992.) The students, then, are involved in the higher-level thinking and decision-making activities usually within the realm of the teacher. With the help of the teacher, students share a zone of proximal development where they can learn questioning, summarizing, clarifying, and predicting activities so integral to metacognitive awareness.

Finally, why does reciprocal teaching work? Collins, Brown, and Holum (1991) posit the following reasons for its success (and, in a broader view, for the success of REALs):

1. The reciprocal teaching model engages students in activities that help them form a new conceptual model of the task of reading. They see reading as a process that involves reflection and prediction rather than just the recitation of words. They learn to make what they are reading relevant to their needs and to monitor their progress and strive for clarification.
2. Teacher and student share a problem context while the teacher models expert strategies that the students learn to use independently.
3. Scaffolding is crucial in the success of reciprocal teaching. "Most importantly, it decomposes the task as necessary for the students to carry it out, thereby helping them to see how, in detail, to go about it" (Collins, Brown & Holum, 199, p. 11).
4. The students play both the roles of producer and critic. They learn cognitive activities that go beyond producing something for the teacher. They learn the self-monitoring activities and thinking processes involved in critiquing and improving their work.

23.4.4 Cooperative Learning

The fourth characteristic of REALs acknowledges the transactional nature of knowledge and suggests that a shift be made to focus on social practice, meaning, and patterns (Roth, 1990). "All cooperative learning methods share the idea that students work together to learn and are responsible for one another's learning as well as their own" (Slavin, 1991, p. 73; see 35.3). Working in peer groups helps students refine their knowledge through argumentation, structured controversy, and reciprocal teaching. Additionally, students are more willing to take on the extra risk required to tackle complex, ill-structured, authentic problems when they have the support of others in the cooperative group. Cooperative learning and problem-solving groups also address students' needs for scaffolding during unfamiliar learning and problem-solving activities; therefore, with the support of others in the group, students are more likely to achieve goals they may not have been able to meet on their own. Constructivists argue that cooperative learning and problem-solving groups facilitate generative learning. Some of the generative activities that students engage in cooperative groups include (Brown et al., 1989):

1. *Collective problem solving.* Groups give rise synergistically to insights and solutions that would not come about individually.
2. *Displaying multiple roles.* Group participation means that the members must understand many different roles. They also may play different roles within the group to gain additional insights.
3. *Confronting ineffective strategies and misconceptions.* Teachers do not have enough time to hear what students are thinking or how they are thinking. Groups draw out, confront, and discuss both misconceptions and ineffective strategies.
4. *Providing collaborative work skills.* Students learn to work together in a give-and-take interaction rather than just dividing the workload.

Research indicates that cooperative learning, when implemented properly, is highly successful. Slavin (1991) provides the following four summary statements regarding research findings in cooperative learning:

1. Successful cooperative learning strategies always incorporate the two key elements of group goals and individual accountability.
2. When both group goals and individual accountability are used, achievement effects are consistently positive. His review found that 37 of 44 experimental/control comparisons of at least 4 weeks' duration found significantly positive effects, with none favoring traditional methods.
3. Positive achievement effects are present to about the same degree across all grade levels (2–12), in all major subjects, and in urban, rural, and suburban schools. Effects are equally positive for high, average, and low achievers.
4. Positive effects of cooperative learning are consistently found on such diverse outcomes as self-esteem, intergroup relations, acceptance of academically handicapped students, attitudes toward school, and ability to work cooperatively.

23.4.4.1. REAL Example: Problem-Based Learning. Another manifestation of REALs is problem-based learning (PBL) (see 7.5, 20.3.4). PBL is "the learning that results from the process of working toward the understanding or resolution of a problem" (Barrows & Tamblyn, 1980, p. 18). It found initial acceptance in the medical field and has grown to become a major learning system for a number of medical, law, and business schools. PBL reflects the REAL attribute that knowledge is constructed rather than received, for it is based on the assumption that knowledge arises from work with an authentic problem (Coltrane, 1993). Benor (1984) states that:

> "Problem-based learning in the context of medical education means self-directed study by learners who seek out information pertinent to either a real-life or a simulated problem. The students have to understand the problem to the extent that its constituents can be identified and defined. The learners have then to collect, integrate, synthesize, and apply this information to the given problem, using strategies that will yield a solution" (p. 49).

How does problem-based learning work? We begin with Coltrane's description of the three fundamental theoretical principles of PBL:

1. Work on the problem begins with activating prior knowledge to enable students understand the structure of the new information. We also saw this principle used in the discussion about intentional learning that emphasized that students must ask themselves what they do know about a subject.
2. We also see the continual reference to the necessity for transfer in PBL, for when the learning context is similar to the situation in which the learning is to be applied, learning transfer is more likely to occur.
3. Learners must have opportunities to elaborate on the information presented at the time of learning in order to enhance their understanding. This is one of the main purposes for using cooperative learning strategies in REALs and was also seen as a part of reciprocal learning.

Savery and Duffy (1994) describe four characteristics of PBL. First, PBL environments include the learning goals of realistic problem-solving behavior, self-directed learning, content knowledge acquisition, and the development of metacognitive skills.

Second, Savery and Duffy state that PBLs are based on problems that are generated because they raise relevant concepts and principles that are authentic. Problems must be authentic because it is difficult to create artificial problems that maintain the complexity and dimensions of actual problems. Recall that we also encountered the need for complexity in the REAL example of cognitive flexibility theory and anchored instruction. Realistic problems also have a motivational effect. They tend to engage learners more because they want to know the outcome of the problem.

Third, the actual presentation of the problem is a critical component of PBLs. Problems are encountered before any preparation or study has occurred (Barrows, 1980). The problem must be presented in a realistic way that encourages students to adopt and take ownership for the problem (Barrows, 1980; Savery & Duffy, 1994). The data must be embedded in the problem presentation (refer back to the example of anchored instruction) but must not highlight the critical factors in the case. Students must make their own decisions about what is critical and what is not because that is cognitively authentic: It reflects actual job performance (Savery & Duffy, 1994).

Fourth, the facilitator has a crucial role comparable to the roles described in anchored instruction and reciprocal teaching. The facilitator interacts with the students at a metacognitive level, helping them ask the right questions and monitor their own progress. Facilitators avoid expressing opinion, giving information, or leading to a correct answer. Their role is to challenge the students (from Savery & Duffy, 1994).

Cooperative learning is a critical component of PBL, for it is used from the beginning through the end of the problem-solution process. The group listens to the problem presentation together. They analyze the problem's components, recall what they know, hypothesize, consider possible resources, and choose directions to go. They test and help each other. They work together on the solutions and reach consensus on final actions. The entire process from beginning to end is cooperative. Cooperative learning is also used for its motivational factors.

> Problem discussion also increases motivation by gaining and maintaining student interest (attention), by relating the learning to student needs or helping students to meet personal goals (relevance), by providing conditions conducive to student success (confidence), and through the motivation provided by that mastery of the task(s) (satisfaction) (Coltrane, 1993, pp. 12, 13).

The PBL is the epitome of the REAL constructive learning process. Students work with problems in a manner that fosters reasoning and knowledge application appropriate to their levels of learning. In the process of working on the problem and with their peers, students identify areas of learning to guide their own individualized study. The skills and knowledge acquired by this study are applied back to the problem to evaluate the effectiveness of learning and to reinforce learning. The learning that has occurred in work with the problem and in individualized study is summarized and integrated into the student's existing knowledge structure.

23.4.5 Generative Learning Activities

The fifth requirement of REALs is that students engage in generative learning activities (see 31.1.1). People who learn through active involvement and use tools build an "increasingly rich implicit understanding of the world . . ." (Brown et al., 1989, p. 33). Generative learning requires that students "engage in argumentation and reflection as they try to use and then refine their existing knowledge as they attempt to make sense of alternate points of view" (CTGV, 1993b, p. 16). Studies indicate that knowledge is more likely to be active and used when acquired in a problem-solving mode rather than in a factual-knowledge mode (Adams et al., 1988; Lockhart, Lamon & Gick, 1988). The concept of generative learning is an extension of the concept of constructing learning. Students cannot construct their own learning without generating something through active involvement.

Generative learning requires a shift in the traditional roles of students and instructors. Students become investigators, seekers, and problem solvers. Teachers become facilitators and guides, rather than presenters of knowledge. For example, rather than simply learning what objectives and goals are, students in a teacher education class generate lesson plans and objectives and then manipulate and revise them to solve new teaching problems. In generative learning, students *apply* the information they learn. Generative learning activities require students to take static information and *generate* fluid, flexible, usable knowledge. Generative learning, then, means that students are involved heavily with projects and creating solutions to authentic problems. A REAL model that relies heavily on projects is cognitive apprenticeship.

23.4.5.1. REAL Example: Cognitive Apprenticeship. Cognitive apprenticeship is modeled after the traditional apprenticeship (see 20.3) way of learning arts and crafts. It incorporates elements of traditional apprenticeship and modern schooling. In apprenticeship, learners see products *and processes* of work. In traditional apprenticeship, the processes of an activity are visible and involve learning a physical and outwardly observable activity (Collins et al., 1991). The expert shows an apprentice how to perform a task, then watches and coaches as the apprentice practices portions of the task, and finally turns over more and more responsibility to the apprentice until the apprentice can perform the task alone (Collins et al., 1991). Traditional apprenticeship deals with processes that are easily visible because they involve skills and producing products.

The goal of cognitive apprenticeship is to make processes that are normally invisible visible. In schooling, the process of thinking is usually invisible to both students and teachers. For example, the practices of problem solving, reading comprehension, and computation are not visible processes (Collins et al., 1991). Brown, Collins, and Duguid (1989) point out that the term *cognitive apprenticeship* emphasizes that apprenticeship techniques can reach beyond observable physical skills to the kinds of cognitive skills associated with learning in schools. In a cognitive apprenticeship environment, the teacher attempts to make visible the thinking processes involved in performing a cognitive task. The teacher first models how to perform a cognitive task by thinking aloud. Then the teacher watches, coaches, and provides scaffolding as the students practice portions of the task. Finally, he or she turns over more and more responsibility to students and fades coaching and scaffolding until they can perform the task alone. "Cognitive apprenticeship supports learning in a domain by enabling students to acquire, develop, and use cognitive tools in authentic domain activity" (Brown et al., 1989, p. 39).

The differences between traditional and cognitive apprenticeship (Collins et al., 1991) are important because they indicate where the effort must be placed on instruction design of learning activities. First, in traditional apprenticeship the task is easily observable. In cognitive apprenticeship, the thinking must be deliberately brought into the open by the teacher, and the teacher must help the students learn to bring their thinking into the open. Second, in traditional apprenticeship, the tasks come from the world, and learning is situated in the workplace. In cognitive apprenticeship, the challenge is to situate the abstract goals of school curriculum in contexts that make sense to students. Third, in traditional apprenticeship, the skills learned are inherent in the task. In schooling, students learn skills that are supposed to move across to different tasks. In cognitive apprenticeship, the challenge is to present a range of tasks to encourage reflection and to identify common transferable elements across tasks. The goal is to help students generalize and transfer their learning.

Cognitive apprenticeship and generative learning are closely linked, because the process of making cognitive processes visible means that students must create or generate things that represent those processes. Teachers must create work and tasks that represent the process of solving a problem, writing, or computation in addition to products. To examine the development of student thinking, an English teacher may ask for questions, themes, concept maps, and outlines before students begin writing. Math teachers are often notorious for telling students, "I want to see your work, not just the answer," so they can look for errors in the thinking process.

The elements of cognitive apprenticeship are present in the examples we have already examined. One of the purposes of reciprocal teaching, which we have already examined, is to teach children to perform some of the tasks of the teacher. Students watch the teacher model the tasks and then practice performing those tasks under the guidance of the teacher. In the Jasper series, students must demonstrate visible signs of the whole problem-solving process by asking questions, forming plans, finding resources, breaking a problem into its parts, and testing possible solutions with each other. In problem-based learning, the students work under the guidance of the teacher to solve real problems.

Generative learning is one of the simplest features of a REAL. It simply demands that students produce something of value. It is probably the most exciting part of a REAL, because students work on projects and tasks that are relevant to them and to their peers. It keeps students busy and happy while helping them learn. It also creates some unique assessment problems, which we will examine next.

23.4.6 Authentic Assessment

The sixth and final REAL attribute is authentic assessment. Conventional schooling relies heavily on standardized and paper/pencil tests to measure the quantity of knowledge that students have accrued. Traditional tests, written reports, and grading schemes are inappropriate measures (Frederiksen & Collins, 1989), are time consuming to administer and score (Williams & Dodge, 1992), and are not always good indicators of how students will perform in actual problem-solving conditions. Williams also states that students are often assessed on skills different from ones that are taught and experience problem-solving assessments that tend to be subjective. Testing and assessment must recognize the importance of the organization of the knowledge base and its connectedness to contexts.

Wiggins (1989) contrasts authentic tests, which he describes as contextualized, complex intellectual challenges with multiple-choice measures that he describes as fragmented and static. According to Wiggins, authentic tests include the following criteria:

1. The intellectual design features of tests and evaluation tasks must emphasize realistic complexity, stress depth more than breadth, include ill-structured tasks or problems, and require students to contextualize content knowledge.
2. Standards of grading and scoring features should include complex multifaceted criteria that can be specified and that are reliable across multiple scorers. What constitutes a high level of performance should be explainable to students and teachers *before* they take the test. Teachers often claim that criteria are subjective; however this is seldom the case, for most criteria can be described with some thoughtful effort.
3. Tests and evaluations must be diverse and recognize the existence of multiple kinds of intelligences. In terms of fairness and equity, evaluations and assessments should allow students to use their strengths within areas that their interests lie.

23.4.6.1. REAL Example: Learning in Design. Carver, Lehrer, Connell, and Erickson (1992) elaborate on this theme by proposing an extensive list of behaviors needed by students in a REAL. In their particular manifestation of a REAL, they consider the classroom a design community in which students design instruction for other students, documentaries for local media, and other exhibits for the community. Their program has the same goals of high-level thinking, reflection, and transfer as other REALs:

> The instructional virtues of these design experiences include the opportunity to develop and coordinate a variety of complex mental skills, such as decomposing a topic into subtopics, gathering data from a variety of sources, organizing diverse and often contradictory information, formulating a point of view, translating ideas into a presentation targeted at a particular audience, evaluating the design, and making revisions based on the evaluations (Carver et al., 1992, p. 386).

Again, there are several parallels with the other examples that we have discussed. Their REAL focuses on complex mental skills; analyzing, comparing, and manipulating information; working on authentic, community-based tasks; and working with others.

To fairly evaluate students working in this environment, teachers need a clear specification of skills students need for design tasks and prescriptions for how teachers can effectively support their skills (see also Agnew, Kellerman & Meyer, 1992). Specification of skills and prescriptions of support are two parts of assessment that must be linked for fair assessment. If a skill cannot be supported by the teacher or some kind of scaffolding technique, then it cannot be fairly evaluated. It may, in fact, be outside the zone of proximal development and beyond the current capability of the student. One of the teacher's jobs in a REAL is to specify skills and performances that can be supported so that the student can grow in ability. Carver et al. (1992) break the important behaviors for their environment into:

1. Project management skills, including creating a timeline, allocating resources, and assigning team roles
2. Research skills, including determining the nature of the problem, posing questions, searching for information, developing new information, and analyzing and interpreting information
3. Organization and representation skills, including choosing the organization and structure of information; developing representations (text, audio, and graphics); arranging structure and sequence; and juggling constraints
4. Presentation skills, including transferring their design into media and catching and maintaining audience interest
5. Reflection skills, including evaluating the process and revising the design

Their criteria work for their learning environment. Other models may need to revise some of the specifics, though the five main categories provide an excellent starting place in specifying skills targeted for assessment. Goldman's (1994) discussion of assessment in the CTGV Jasper series suggests the following assessment areas: assessment of complex mathematical problem solving (math is the content domain of Jasper), measures of group problem-solving performance, assessment of extensions into other areas of the content area, and assessment of cross-curricular extensions. While conducting an assessment for a REAL is more work than conventional assessment, it is also an integral part of the learning process rather than a periodic quantifiable measure. Authentic assessment provides feedback and information that is useful for planning future learning.

23.4.6.2. Assessment of the REAL. There is yet another dimension to the issue of assessment: evaluation of the environment. To examine this, I'll look at another example of a REAL, case-based learning (CBL). "Case-based teaching exploits the basic capacity for students to learn from stories and the basic desire of teachers to tell stories that are indicative of their experiences" (Shank, 1990, p. 231). In case-based learning, teachers first teach students what they need to know to become interested in the case that will be examined. This, incidentally, is the prime difference between case-based learning and problem-based learning.

> PBL problems differ from the typical case history in that they [PBL teachers] do not (initially) provide or synthesize all the information needed to solve the problem. In PBL, the problem is presented first, before students have learned basic science or clinical concepts, not after (Albanese & Mitchell, 1993, p. 53).

The information in CBL is presented to students in the form of stories. Students work with each other to analyze the stories or cases to abstract rules, heuristics, or practices that may be transferable to other cases. In CBL, the information is present within the case; students do not have to pursue other resources or individualized plans to learn more information as they do in PBL. Again, the main attributes of REALs are present: constructing knowledge, personal responsibility, cooperative learning, authentic context, and generative learning activities.

Williams (1992) developed a framework for comparing and evaluating methods of case-based instruction in the areas of teaching and learning and materials and curriculum. She poses 10 questions to guide the evaluation of case-based instruction (pp. 375–76):

Teaching and Learning

1. Does instruction begin with a problem to be solved?
2. Does the teacher model expert problem solving in the context of a complex problem?
3. Are students given the opportunity to engage actively in solving problems, and does the teacher provide specific immediate feedback while students are solving problems?
4. What type of scaffolding is used to support students as they solve problems?
5. Does instruction emphasize metacognitive strategies as well as domain knowledge?
6. Are there frequent opportunities for both teacher and students to assess how well learning is progressing? Is the type of assessment used appropriate for measuring the skills that are taught?

Materials and Curriculum

7. Are the problems authentic; that is, are they ones that would be solved by practitioners?
8. Are the problems realistically complex? Do their solutions involve multiple steps? Are the settings rich and detailed? Are multiple skills and concepts linked to each problem?
9. Are the problems presented in a way that makes complexity manageable, for example, using a story format, presenting them on video, and providing all relevant data?
10. Are problems sequenced to support students' needs at different stages of learning?

These questions apply to all REALs, not just case-based learning implementations. This common utility of these evaluation questions is another example of how much each of the examples of REALs that we have examined hold in common.

23.4.6.3. Evaluation Techniques. Assessment in REALs means that we have to consider more varied techniques. Neuman (1993), in her work with the Perseus hypermedia program, suggests several alternatives. First, she suggests that teachers use more observations, including evaluator observations of performance processes, think-alouds by students, and automatic transaction monitoring. Second, she suggests using interviews of students, instructors, and staff using both questionnaires and focus groups. Finally, she suggests the use of document and product analysis including assignments, syllabi, essays, journals, paths, reports, documentation, and presentations.

The issue of assessment is one of the more complex attributes of REALs because it is multidimensional. Assessment involves simultaneous assessment of both students and the environment. It also represents more than any other single attribute the depth of change necessary to implement a REAL. The move from paper/pencil tests to portfolio analysis, observations, interviews, and document analysis more than any single attribute signals the radical difference between REALs and conventional instruction.

23.4.7 Conclusion of REAL Characteristics Section

We have looked at each of the six main characteristics of REALs: (1) constructivist heritage, (2) authentic instruction, (3) student responsibility, (4) collaborative learning, (5) generative learning activities, and (6) authentic assessment. Each characteristic of REALs builds on and uses the other. None is mutually exclusive; one is no more important than another: You cannot talk about one feature without incorporating the other. In effect, the characteristics of REALs mirror the comprehensive and integrated nature of REALs. The characteristics are symbiotic, with one feature both supporting and needing the others to create a successful, rich environment for active learning. In the next section, we examine some of the research related to the effectiveness of REALs.

23.5 RESEARCH AND REALS

Current research issues within the field of REALs center on their overall effectiveness, methodological issues in conducting research, and making cognitive processes visible. Research conducted in the field parallels the development of REALs. REALs have developed in theory and implementation from content area teaching strategies used occasionally to integrated and comprehensive strategies guiding a whole curriculum. Research has evolved from comparing REALs with conventional teaching to studies focusing on how learners think and perform differently using REAL strategies. In the following literature survey, we begin with a look at the overall effectiveness of REALs and then move on to narrower issues related to learning and implementation.

23.5.1 REAL vs. Conventional Instruction

Research comparing REALs with conventional instruction is generally quite favorable, finding REALs equal or superior to conventional instruction in teaching both problem-solving skills and content. I summarize several studies below that examine the overall effectiveness of a particular implementation of a REAL. Some are more successful than others. In my review, I attempt to bring out some of the methodological issues related to conducting research with REALs and suggest future research opportunities.

23.5.1.1. The Jasper Series. In one of the most extensive comparisons of a REAL versus conventional instruction, James Pellegrino and his CTGV colleagues (1991) tested the Jasper series in 16 schools in 9 states. Two teachers and a corporate support person had responsibility for implementing the program over the course of the 1990–1991 school year at each site. Teams received intensive 2-week training in the program before implementation. The CTGV group developed assessment strategies to evaluate Jasper's main goals for students: (1) to develop critical mathematical problem solving and reasoning skills, (2) to develop an appreciation of mathematics as a realistic part of their world and everyday problem solving, and (3) to develop various sets of specific mathematical knowledge and skills.

Pellegrino's group made a thorough attempt to measure changes in children's mathematical skills and attitudes over the course of a year. They used a battery of paper/pencil tests administered at the beginning and end of the school year to examine basic math concepts and content, attitudes toward math, word problem–solving skills, and higher-level problem-solving skills. Mini versions of these tests were administered at midyear. The Jasper classes were compared to children in classes that did not use the Jasper program.

23.5.1.1.1. Math Attitudes. The CTGV team used a 35-item questionnaire that covered 11 different categories about attitudes and exploration and attribution behaviors. Although the reliabilities were low on the attitude scales (probably because of too few items), Jasper groups had more improved attitudes toward math at the end of the year compared to the control groups, believing that math was more fun and interesting than they did at the beginning of the year. However, despite the improved attitudes, Jasper students showed no greater desire to study or explore math than the control groups. Nor did the Jasper students attribute any more of their success to their own abilities than they did at the beginning of the year, for they still saw the teacher as the main force guiding their learning. It seems difficult to assess attributional and exploration behavior from a test. Future research might examine growth behaviors related in independence and personal responsibility to see if Jasper affects the development of intentional learning using observational techniques to supplement test instruments.

23.5.1.1.2. Basic Math Concepts. The Jasper content covered time and distance, area, perimeter, and volume, fraction/decimal conversion, representation of fractions, and units of money, weight, and length. The Jasper students received no explicit instruction in these concepts, because the Jasper teams believed that Jasper provided a strong context in which students could anchor their learning of the concepts. Pellegrino used paper/pencil tests and word problems to examine students' skills. No main effects or interactions were found for gender. On tests of basic math abilities for decimals, fraction/decimals conversion, and area/perimeter/volume, Jasper students had significantly larger increases in performance across the school year than the control groups. The study also used word problems to test "near transfer" of Jasper problem-solving skills. The word problems were a mix of one-step, two-step, and multistep problems. The Jasper group significantly outperformed the control group on all three problem types at year end, demonstrating greater problem-solving skills.

23.5.1.1.3. Planning Skills. One of the main goals of both Jasper and REALs is to teach students to become better problem solvers. Pellegrino et al., in the thoroughness that characterizes this study, created experimental planning problems to assess higher-level planning, subgoal comprehension, and calculation ability for the two Jasper subject areas: trip planning and sampling for business plans. The Jasper students were significantly more skilled at identifying the goal of the problem and in breaking the problem down into the smaller components or subgoals that lead to the solution.

23.5.1.1.4. Standardized Achievement Test Scores. Realizing that no innovation will be adopted in schools if it does not deal with the political realities of standardized testing, Pellegrino compared the standardized achievement scores of Jasper to the control group. This was a difficult task, and results were difficult to interpret, because not all of the sites had scores to compare, and five different tests were used across the sites. The Jasper students tended to perform slightly better than the control group, but not significantly so. Results are probably always going to be difficult to interpret because of the differences between the purposes of testing and the purposes of the instructional strategies used in REALs. However, the issue of standardized testing will not go away, and more structured studies need to be conducted.

23.5.1.1.5. Strengths and Weaknesses. Although experimental researchers may consider this study as "too uncontrolled" to be generalizable, I hold the contrary belief. This study is one of the most thorough and objectively reported that we have read in this field. It is a broad study using many schools and teachers incorporating qualitative and quantitative measures. Rather than trying to control every single factor within the classroom, it treated those factors as natural elements of the study. (I will examine later a study that tried to control too many factors.) When the researchers found anomalies in the quantitative results, they used their observations of the classrooms to find explanations. One of their most significant strengths is their effort to find out why their students scored as they did, not just what their students scored, although the researchers themselves criticize their measurement instruments as lacking sensitivity for this kind of research. They also need to rely less on paper-and-pencil tests and test the students in the way that Jasper works, in a team approach to problem solving. They also did not measure the effect of group participation or the growth individuals showed in their ability to work within groups. Finally, the reactions of administrators, colleagues, and parents to the program need examination.

23.5.1.2. Stoiber's Research in Teacher Education. Most research with REALs begins from a desire to develop instructional strategies that help students become more thoughtful and cognitively flexible so that they can perform better in realistic problem-solving situations. Often, the standard we hold our students to is that of the expert job performer. It is the expert's behavior that we wish to teach to our students. For example, Stoiber (1991) states that expert teachers are more thoughtful and have more developed knowledge structures to support reasoning and problem solving when managing classrooms. They also have a highly developed sense of responsibility for student motivation and achievement in the learning environment. In a study at the university level with preservice teacher education students, Stoiber found that a REAL strategy was more effective in developing reflective teachers than conventional instruction. Stoiber looked at 67 students in a teacher education program who had no experience in classroom teaching or management. The students were divided into technical, reflective, and control groups. Instruction in classroom management concepts was conducted over ten 50-minute sessions that met weekly.

23.5.1.2.1. Technical Condition. The technical approach is based on an orientation that portrays learning as acquiring concepts, principles, and techniques. The instructor emphasized prescribed principles using a review-lecture-student participation format. Modeling and role playing were also used.

23.5.1.2.2. Reflective Condition. The reflective approach, on the other hand, stresses the construction of concepts and principles based on existing knowledge structures. In the reflective condition, students analyzed classroom cases that focused on cognitive functions corresponding to three stages of teaching: preteaching (planning), interactive teaching, and postteaching. In the preteaching phase, students used self-inquiry methods to activate prior knowledge. They constructed mental representations of classrooms, including situations, decisions, actions, and outcomes visualizing situations and asking themselves what they would do in certain circumstances. In the interactive phase, students would "think aloud" while solving classroom case situations to help them become more conscious of the steps or strategies undertaken during classroom management. The postteaching phase involved self-evaluation comparing goals, intents, and images of teaching to teaching outcomes.

23.5.1.2.3. Control Condition. In the control condition, students were instructed in education practices not related to classroom management. Students received excerpts of readings on an unrelated topic and examined vignettes and wrote short responses.

23.5.1.2.4. Instrumentation. Stoiber was creative in her measurement of student behaviors. She examined pedagogical reasoning and problem-solving performances. To examine pedagogical reasoning, she individually administered a video-stimulated interview of participants.

> This measure examined participants pedagogical reasoning by stimulating their thinking about classroom management. The participants viewed a videotape of four classroom situations depicting classroom management problems (e.g., children whispering during a test, children not paying attention) role-played by an elementary teacher and her students. Each classroom problem vignette consisted of a classroom management incident prior to the teacher intervention. At the end of each videotape segment, participants were asked what action they would take if they were the teacher. Then to assess their pedagogical abilities, they were asked: "Why did you decide on this particular action/response?" (Stoiber, 1991, p. 134).

Interviews were audiotaped and coded for pedagogical reasoning by two advanced graduate students. The students' reasons were rated on a three-point scale: (1) contains no or limited reasons, (2) contains adequate or specific reasons supporting viewpoint or decision, and (3) contains elaborate or ethical reasons. Interviews were also coded for expressions of teacher responsibility related to (a) student affect, (b) student cognition, and (c) learning environment.

She measured problem-solving performance by examining student ability to solve management problems assessed using video-stimulated interview. Students watched a teacher deal inappropriately with the problem and were asked, "What suggestions would you offer for improving outcome?" Interview responses were coded in terms of five problem-solving strategies: (a) problem identification (identification or clarification of the problem), (b) generating alternative plans and solutions, (c) reflecting on the consequences of the plan's actions, (d) self-awareness and metacognitive activity during the interview, and (e) evaluative skills for reflecting on and critiquing teaching. Finally, they completed a problem-solving inventory.

23.5.1.2.5. Results. In the pedagogical reasoning analysis, the students in the reflective condition showed more expertlike behavior than those in the technical or control conditions. Their reasons for supporting their suggested actions were rated higher than were technical or control groups. They reported significantly more concern about student affect/attitudes more often than technical condition and mentioned being responsible for student cognitive performance significantly more often than control condition. They took significantly more responsibility for a positive learning environment than either technical or control groups.

The reflective group was also more sophisticated in its problem-solving skills. The reflective group offered significantly more suggestions for alternative ways to handle the videotape situation than either other condition. The reflective group reflected significantly more often on the consequences of their decisions than the control group and reported significantly more alternatives for evaluating teaching practices than both the technical or control groups. The reflective group also exhibited more metacognitive awareness for improving poor pedagogical practices than the technical group and reported more frequently perceptions of themselves as solving problems in a manner associated with success than did the technical and control groups.

"The results of this study provide evidence that preservice teachers are capable of constructing concepts and developing the cognitive abilities needed to make sense of challenging classroom situations" (Stoiber, 1991, p. 137). Like the previous Jasper study, Stoiber's study is an excellent example of research with REALs. It combines qualitative and quantitative observations that not only measure the effects of the reasoning and problem solving skills but also explains why one group is more expertlike than another. However, like the Jasper study, we still need to see if this kind of development transfers to actual performance on the job.

23.5.1.3. Problem-Based Learning. Wilson and Cole, in Chapter 22, provide an extensive review of problem-based learning (PBL). I briefly summarize a review of PBL research in medical education by Coltrane (1993) to examine its overall effectiveness as a learning environment. The research on PBL is less conclusive than the research reported in the last two studies. Coltrane (1993) found too little data to determine conclusively that PBL is superior to conventional instruction in preparing physicians, though she found PBL at least equal to conventional instruction. The question of whether PBL is equal to or better than conventional instruction is important. REALs are usually viewed as more expensive in terms of time, effort, and resources than conventional, didactic instruction. Should PBL or REALs be adopted if they are not better than conventional instruction? Coltrane reports that Berkson (1993), in a meta-analysis of 12 PBL studies, found no direct advantage of one medical curriculum over another (PBL vs. regular). On the other hand, Mennin et al. (1993) found that PBL students outperformed conventional students in the later years of their study when self-directed, less-structured, and more independent learning experiences were encountered in their residencies. This last finding is critical, because, like the two previously discussed studies, it finds that PBL students improve the problem-solving skills that are a major component of high-quality, diagnostic performance. We also point out that the PBL research is more concerned with content acquisition than intentional learning and specific cognitive processes.

The concern for content coverage is also a concern of teachers thinking about adopting REAL teaching strategies. Teachers fear that their students will sacrifice breadth of content if they focus on the opportunity for depth that REALs afford. There is also the concern that the new teaching strategies will not prepare students for standardized achievement tests. However, the data in this area are generally positive. Dolmans (1993) found that PBL learning activities covered an average of 64% of intended course content. However, the coverage actually increased when students generated learning issues in response to their own needs, because half of those issues were judged relevant to course content. In terms of covering prescribed objectives, Rangachari (1991) found that students brainstorming about PBL problems identified and exceeded all of the faculty objectives. Blumberg and colleagues (1990) found adequate consistency between student issues and objectives generated by faculty. Coulson and Osborne (cf. Coltrane, 1994) discovered that PBL student groups identified an average of 61% of faculty objectives deemed essential.

So, although the research on problem-based learning does not conclusively find that REAL strategies are better than conventional teaching in all regards, it does lend strong support. PBLs are at least equal to conventional instruction and probably better as the need for problem-solving and independent learning skills grow. Content and learning objective coverage may not be as systematic; however, research indicates that it is more than adequate.

23.5.1.4. Reciprocal Teaching. Another research question for REALs is whether they are useful for populations with special needs. Palincsar and Klenk (1992) investigated the effect of their intentional learning environment, reciprocal teaching, with young, at-risk children. "Young children with learning disabilities typically encounter difficulty with academic tasks requiring intentional effort and effective use of metacognitive skills—qualities that competent readers and writers possess" (Palincsar & Klenk, 1992, p. 211). Special education teachers often deal with these problems with greater decontextualization, isolating basic skills and drilling and practicing without context. However, Palincsar and Klenk contend that such instruction contributes to limited notions of literacy and fails to teach elements of intentional learning. So, they developed the reciprocal teaching strategies to place reading within a more meaningful context and to teach the intentional learning skills many learning-disabled children do not use.

Reciprocal teaching emphasizes the social nature of learning with a focus on students learning many of the executive control functions usually considered the exclusive province of the teacher. Reciprocal teaching helps students learn these skills through appropriate questioning and dialogues about reading materials (see earlier in this chapter for a more detailed description of reciprocal teaching). The primary academic goal of Palincsar's program is to improve reading and listening-comprehension skills. In reciprocal teaching, students and teachers take turns leading discussions about the content of a text that they are trying to understand. The strategies used encourage the self-regulation and self-monitoring behaviors that promote intentional learning. Baseline studies indicate that at-risk students score typically below the 40th percentile in achievement and about 30% correct on independent measures of text comprehension on entering a reciprocal teaching study (Brown & Palincsar, 1989; Palincsar, 1990; Palincsar & Brown, 1989). After 3 months of instruction using reciprocal teaching, 80% met the criteria for success (75% to 80% correct) on measures of comprehension, recall, ability to draw inferences, ability to state the gist of material read, and application of knowledge acquired from the text. The students, both primary and middle school, maintained those gains 6 months later.

In another study (Palincsar & Klenk, 1992), results show that children with learning disabilities benefit significantly "from strategy instruction occurring within classroom cultures that support collaborative discourse, the flexible application of comprehension strategies, and appropriate, meaningful opportunities for reading and writing" (p. 211). In this study, which we will examine in detail, Palincsar and Klenk used 6 teachers and 30 first-grade children who typically scored below the 35th percentile on a standardized test of listening and comprehension. The children worked with a set of texts covering related science concepts.

23.5.1.4.1. Pretests. The study began with a pretest to measure comprehension and knowledge of the science principles. The comprehension test was administered by reading a passage aloud to a student and then asking questions. This testing procedure was used regularly throughout the study. At the time of the pretest, the experimental and control children attained 47% correct. In identifying the theme of the passage, 29.2% of the experimental students were successful compared to 27.2% of the control group. A classification and sorting task was used to assess the children's ability to identify and use the analogy underlying the various topics. The teachers presented the children with pictures and asked them to put the pictures that go together in one pile and the other pictures in another pile. At the pretest, 43% (37% control) of the sorting decisions by the experimental groups were based on physical characteristics of the objects, and only 13% (14% control) were based on thematic characteristics.

23.5.1.4.2. Methodology. After the pretest, one passage was read to the students each day for 20 days. The basis of the procedure was reciprocal dialogues (see the actual article for sample dialogues). The children and teacher took turns leading discussions in which they questioned one another about the content of the passage. The group summarized the content, generated predictions about upcoming text, and clarified ambiguous information.

23.5.1.4.3. Results. The children in the experimental group made outstanding progress in 20 days. After the first 10 days of instruction, the experimental group attained 49.9% (37.7% control) correct on the comprehension measures. During the second 10 days, they attained 70.6% (39.5% control) correct. In their ability to identify the theme of the passage, the experimental group was correct 45.5% (14.9% control) during the first 10 days. During the second 10 days, this rose to 63.9% correct (10.5% control). On the classification task, the experimental group attained 53.1% correct (27% control) during the first half and 76.6% correct (17.3% control) during the second half.

Palincsar's and Klenk's work is another model study—difficult and complicated, but valid and authentic. They designed the study carefully, trained the teachers, and conducted measurements that indicated thought and development in the students, not just knowledge acquisition. The measurements and tasks were authentic and fit within the normal range of classroom activities. Their study was thorough and included the most important dimensions of reciprocal teaching: discourse patterns among students and teachers, playfulness, the role of the teacher, and the role of the text. Palincsar and Klenk managed to conduct research with REALs in the most unobtrusive and authentic way possible.

23.5.1.5. Meaning Versus Algorithmic Math Teaching. In a year-long study of 40 eighth-grade mathematics classrooms comparing teaching with meaning, teaching with algorithmic strategies, and conventional teaching strategies, Sigurdson and Olson (1992) found significant effects for teaching with meaning. Both the algorithmic teaching and meaning strategies were considered innovative treatments. They defined algorithmic teaching as teaching math emphasizing computational performance and automatic application of mathematical rules. They defined "teaching with meaning" as "teaching in context." Students used physical and pictorial objects to represent mathematical concepts, placed concepts in familiar applications, and performed mathematical interpretations. The conventional classrooms were control groups using typical strategies. Included in their study was a long-term training program to help teachers learn either the algorithmic or meaning strategies, though the training program ran concurrently with the classroom treatments. Reported results are based only on the teachers who were considered successful implementers of the strategies.

The results of the study are a bit difficult to interpret, because they make a distinction between class ability and student ability, the relevance of which is hard to understand. It is also difficult to find the results that were "significant" over those that "showed trends." However, generally, the students in the classes of teachers who successfully implemented the teaching-with-meaning strategies had the highest achievement at the end of the year on a posttest. The above-average classes showed much greater gains in performance under the meaning strategies, while the below-average performed equally poorly under all strategies. In terms of individual abilities, higher-level students performed well under any strategy, while the middle-level ability students did better with the meaning strategy. The lower-level students did poorly with all strategies. Sigurdson's and Olson's study is a complex study fraught with all of the confounding problems of doing research in this area: individual ability levels, different classes, different teaching styles, the difficulty in achieving consistency among treatment classes, teacher training, and teacher cooperation. They may have had poorer results with the lower-ability students because their definition of "meaning" and "context" was severely limited. The teaching-with-meaning activities, though aimed at a deeper understanding of the concepts, lacked the authenticity level found in the Jasper series. The training program may have also had a negative effect on class achievement because some teachers may have grasped and implemented the strategies before others. The significance of their study is in the questions raised related to individual differences and abilities.

23.5.2 Narrower Issues

The above findings show that REALs work in a general way. Jasper teaches math and problem-solving skills. Stoiber's teacher education program taught preservice teachers to be more reflective and creative in solving classroom management problems. Problem-based learning covers the content and teaches problem-solving skills. Reciprocal teaching places reading in context and teaches students to be more reflective and metacognitively aware while reading. Teaching math with meaning is more successful for some learners than an algorithmic approach. Now I examine some more specific issues related to the effectiveness of REALs, including problem solving and transfer, tutors and content expertise, attitude toward content, and effects on cognitive structure.

23.5.2.1. Problem Solving and Transfer. One of the main assertions of REAL developers is that REALs improve problem-solving skills and enhance the likelihood that learning transfers to new situations. To accomplish this goal, REAL strategies do three things: (1) They make relevant problem-solving skills explicit; (2) they use context and authenticity to avoid the problem of inert knowledge; and (3) they have students deal with complex problems in complex ways.

23.5.2.1.1. Making Skills Explicit. Susan Williams and her colleagues at Vanderbilt (1992) found that without prior instruction in "what-if" thinking, students often have difficulty in knowing which aspects of their previous knowledge should remain intact and be used in a new problem. In her study, Jasper and control students watched a Jasper adventure. The Jasper students received instruction in the Jasper program, and the control students worked in a traditional math curriculum. Following instruction, students received a what-if problem related to the Jasper program. (A what-if program changed some variables in the original Jasper program.) Students were asked to talk aloud while solving the problem. The protocols were analyzed for the number of subgoals (16 necessary) attempted and the type of reasoning used. The Jasper students attempted to solve more subgoals than the control students. The Jasper work had made the problem-solving process more visible to them.

23.5.2.1.2. Inert Knowledge. The Jasper students in Williams's study also tried to make use of the declarative knowledge from the previous computations by applying it to the new problems. They may not have been right in their application, but the knowledge they learned provided a context for them to work in and did not remain inert. It helped them become active problem solvers. A number of other studies (Asch, 1969; Bransford et al., 1990; Brown et al., 1989; Gick & Holyoak, 1983; Ross, 1984; Stein, Way, Benningfield & Hedgecough, 1986) have found that when subjects are not explicitly informed about the relevance of knowledge to a problem, they do not use the knowledge—it remains inert. Bransford (1990) found that students who received statements that explicitly related acquired knowledge to problem statements were more likely to use that information during problem solving than subjects who did not receive statements drawing explicit links to the problem and their knowledge. Explicitly stating these relationships in the problem presentation helped students understand how information permitted a solution to that problem. Prior information that was recalled was then used more spontaneously.

23.5.2.1.3. Complexity. Real-world problems, that is, problems outside the classroom, are usually complex, requiring multiple substeps to solve. Yet, in classrooms, we have a tendency to limit problems to one or two steps. Students do not learn how to deal with multistep problems. The best way to teach complex problem solving, then, is to have students deal with complex problems in authentic contexts (CTGV, 1993d).

23.5.2.1.4. Far and Near Transfer. The Cognition and Technology Group at Vanderbilt (1993d) found that making processes explicit, drawing explicit relationships with existing knowledge, and using natural complexity improved problem-solving skills faciliates transfer. In one study, the CTGV examined a high-achieving fifth-grade math class for near transfer. Students were assigned to a Jasper instruction group or a word problem group. They were given tests to assess learning and transfer before and after four 1-hour instructional sessions. Students in the Jasper group scored much better on a mastery test of the Jasper program. The transfer test assessed transfer from Jasper to a highly similar problem. Students watched the transfer video and then solved the problem while talking aloud during an interview procedure. Their interviews were scored on whether they mentioned, attempted, or solved the major subproblems of the problem. The Jasper students scored higher than the word problem students. More than 75% of the Jasper-instructed group solved at least one of the top-level goals, compared with less than 20% of the word problem groups. These findings are also supported by

Van Haneghan et al. (1992), Goldman with CTGV (1991), and Goldman et al. (1991).

In a second study by the CTGV, the groups were tested on another transfer problem that was not isomorphically the same as the instructional problem—a far-transfer problem. Again the Jasper students scored significantly higher than the word-problem students. Jasper students mentioned, attempted, and solved a greater number of subproblems, even though the problem-solving steps were not the same as those encountered in the instructional program. This suggests that the Jasper-instructed students may have learned a general heuristic from the instruction.

On the whole, these findings suggest optimism about the value of REALs in teaching general problem-solving skills and transfer ability. Yet, there is still much work to do related to transfer. The distinction between near and far transfer is a continuum and not a dichotomy. The problem type, learner experience and intelligence, and problem context all play roles in determining what is near or far. What is far for one student may be near for another. What about transfer outside the classroom and across the curriculum? How successful are students in completely new environments? Are Jasper students able to apply anything they know to social studies, language arts, or science? The question of transfer is really the bottom line of REAL research. We justify REALs because our students are currently poor at transferring what they know. Are we improving?

23.5.2.2. Tutors and Content Expertise. REALs change teachers' roles by making teachers a greater part of the process of learning rather than the delivery of information. Teachers are often seen as equal participants in the learning process with students. This raises questions regarding their content expertise. Do teachers who are learning along with the students need to be experts in the content area? Or, since teachers are learning along with the students, do they only need to be experts in the learning process? The problem-based learning literature sheds some light on these questions.

Coltrane's (1993) review of PBL studies supports the contention that tutors should be experts in content. Students guided by content-expert tutors achieved better learning outcomes and spent more time on self-directed learning when their teachers were content experts. Expert tutors generated twice as many learning issues that were 3 times more congruent with case objectives than nonexpert tutors. However, Coltrane also found a disadvantage to expert tutors. Expert tutors tended to retain too much control of the learning process: They are more directive, speak more frequently and for longer periods, and more directly answered student questions, though they do suggest more discussion topics than nonexperts. Silver (1991) found that groups with expert tutors are less likely to be student directed.

It appears that good training of teachers may remedy the difficulties. Content knowledge balanced by an ability to "let go" and surrender control may be the best choice.

23.5.2.3. Attitude Toward Content Area. The Pellegrino et al. (1991) study (described above) found that students who used the REAL Jasper series had improved attitudes toward mathematics. In another, more loosely structured program, Myers (1992) studied the effects of using *The Voyage of the Mimi* in middle-school classes on female students. Mimi is a program that uses thirteen 15-minute video segments about a scientific expedition to study the Humpback whale. One of Mimi's main goals is to help integrate science across math, language arts, science, and social studies curricula boundaries promoting higher-level thinking activities. Students using the Mimi adventure spent the first period of the day viewing the day's adventure and then left for their other classes, rotating in and out of math, science, English, and social studies classrooms. The math teacher used a Mimi module on maps and navigation to study map making, measurement, distances, latitude and longitude, triangulation, rations, and time-and-distance problems. The science classes studied the scientific method, food chains, and food webs. The English teacher had students keep journals, pretending to be a Mimi crew member. They also studied ethics of whaling, communication, and poetry. The social studies teacher conducted research on endangered species, paleontology, evolution, codes, and land forms.

The observer and teachers were struck by the enthusiasm students showed to studying Mimi-related subjects. Anchoring the study of the content areas into a realistic context was highly motivating. To study attitudes of female students toward the math and science content, Myers administered before-and-after attitude questionnaires. Myers administered the postexercise questionnaire 2 weeks following the unit. The prequestionnaire showed no difference in attitudes towards math and science between male and female students. The postquestionnaire showed no improvement from the start of the exercise till the end for the female students.

There are several possible reasons for this. First, the study lasted only 2 weeks, which is hardly enough time to effect lasting attitude change (see Chapter 34 for a discussion of media and attitude change). Secondly, in Myers' view, the teachers tried to maintain their traditional approach to instruction, adhering to behavioral objectives and county and state guidelines. They became more flexible through the unit, but were as much "guinea pigs" as the students. Third, he conducted no advance training for the teachers. If they were unprepared to change their attitudes, it is hardly reasonable to expect a great change among the students. Finally, I question the integrative nature of the study. The students had a common topic, but moved from class to class in a compartmentalized way. That is hardly an integrative approach to instruction, for in most integrative approaches, the teachers work together and in teams with their students. So, the effects of REALs on student attitudes toward content is still an open issue.

23.5.2.4. Cognitive Structure. The theoretical models of Ausubel (1968) and Gagné and White (1978) suggest that "connections" among propositions, images, episodes, and intellectual skills within a person's cognitive structure promote understanding and transfer. "These models also imply that, to understand new concepts, one must anchor the new concepts to existing structures" (Robertson, 1990, pp. 253–54). However, as David Jonassen (Jonassen, 1994a) is fond of saying, "The cerebra-scope has not yet been invented," so a clear picture of a person's cognitive structures that support conceptual understanding does not exist. However, research to visually approximate these cognitive structures has been conducted using pathfinder and multidimensional scaling analyses.

One of these methods uses cognitive maps representing the perceived relationships among several pairs of concepts associated with a specific topic using pathfinder techniques. Dunlap and Grabinger (1992) examined the effect of working within a computer-supported learning environment on participants' knowledge structures about learning environments. They conducted a class that studied the attributes of REALs. At the beginning of the class, they used KNOT-Mac (Interlink, 1990) to rate the degree of relatedness among 17 concepts about REALs. The KNOT-Mac program uses pathfinder analysis techniques to produce a map representing the user's knowledge structure. At the end of the class, the students rated the same 17 concepts. Average maps representing the class starting map, class ending map, and an experts' map were compared for similarity and complexity. Their findings indicate that after working within the learning environment the participants' ending map (the average map for the whole class) became much more complex and sophisticated than the average beginning map. However, the class map did not replicate the average experts' map. This was to be expected, since the experts had worked with the concepts in different ways and for a longer period of time than the students.

One of the unexpected benefits of using the maps was that the students became involved in analyzing their maps. First, they tended to ask, "Is my map right or wrong?" assuming the map was some kind of test. After being convinced that the map was no test, they began to ask themselves why certain concepts were linked and other weren't. They wanted to refine their understanding of the concepts.

Robertson (1990) implemented REAL strategies to teach physics problems related to Newton's second law. He used strategies to contextualize the students' learning to ensure that both internal and external associations were among the criteria attributes of a principle. Internal associations are connections among the criteria attributes of a principle. External associations refer to connections between the principle and everyday experiences or context. He used student-generated concept maps to help analyze the understandings that students had of Newton's second law and the related concepts. Robertson gave students practice with a number of problems. One set of problems was highly similar and another set was both similar and varied, requiring further transfer. The similar problems focused on internal connections, while the varied problems helped students make additional external connections. Using the maps, he rated the level of understanding students had of the system, looking at both internal and external connections. He found that 86.5% of variance for predicting success in solving the physics problems could be attributed to system-concept understanding developed through practice with several kinds of problems. The maps and problem performance indicated that students who practiced with both similar and varied problems to develop external and internal connections were more successful. The maps helped indicate and show visually the kinds of connections they made.

Pathfinder networks and concept maps can provide visual data to help interpret and analyze the progress of student thinking processes. They are complex and difficult to use and subject to student resistance because they take much time to generate. But, when used carefully and with student acceptance, they can be quite revealing and a valuable qualitative research tool.

23.5.3 Research Conclusion

On the whole, research into implementations of REALs shows positive effects for the REAL strategies. These positive effects show across ages, abilities, and content areas. However, research into the implementation of REALs is still young and developing. At the same time that teachers are trying to change their classrooms from the teaching of decontextualized skills to the teaching of lifelong learning skills in context, educational research is struggling to move from a history of decontextualized experimental studies to more qualitative kinds of research within the natural context of the classroom. Both teachers and researchers have a lot to learn in terms of methodology in each area.

23.6 METHODOLOGICAL ISSUES

Performing studies with REALs is raising two important issues in instructional technology research methodology. First, the movement from experimental research methods to qualitative research methods is affecting the way in which researchers conduct their studies and report their results. Second, the field of instructional technology has had a fixation on performing research about media rather than about methods and learning. (Part VII of this text covers these issues and others in a more thorough manner.)

23.6.1 Experimental versus Qualitative Issues

Much of the current debate in educational research centers on experimental versus qualitative and naturalistic strategies. While I see the value for both kinds of research, I argue that professional researchers need to expand their conceptualizations of research methodologies when investigating the effects of REALs. Bissex (1987, p. 12) holds that

> The assumption of external and controllable causation would seem to underlie all studies based on experimental and control groups. Yet observational studies of children's language development and preschool literacy have revealed children to be creators rather than mere recipients of their learning (p. 12).

Bissex's statement mirrors the same issues we presented at the beginning of the chapter when discussing conventional versus REAL teaching strategies. A conventional classroom is didactic, based on the assumption that learners receive their learning from a controlling teacher. A REAL classroom is founded on the assumption that learners are the managers and creators of their own learning under the guidance of a teacher. She goes on to argue that experimental research focuses on issues of *teaching* and control, while observational studies focus on issues of *learning* and internal processes. It seems logical, then, to expect that new teaching methods demand new research methods.

Another factor in the methodological debate is the issue of generalizability. Bissex again argues that experimental research has limited generalizability because of the artificial nature of controls placed on treatment interventions. Experimental researchers try to isolate some factors and eliminate others; however, this is does not reflect the natural events within classrooms. Qualitative research, including observational and case study methods, forms more generalizable theories because the results are based on natural classroom and learning events that encompass many of the factors that influence learning and student behavior.

Bissex also argues that researchers must come to know the people they are working with quite closely. This is contrary to experimental studies where the researcher attempts to maintain distance from the subjects for fear of contaminating the results of the experiment. In observational techniques, researchers must take time to see their students in many situations and gain their confidences to gain valid and realistic perspectives of how the many factors in instruction are affecting the learners.

Again, I state that there is a role for both kinds of methodologies, usually within the same study. However, we do hold that Bissex's comments are valid and present good reasons for adopting more qualitative research methodologies. REAL classrooms are complex, with many factors in operation. They are, in essence, uncontrollable. To understand what is happening with students and teachers in the classroom, we cannot isolate or eliminate variables because we would be destroying the natural environment. The results would be meaningless.

For an example of some the above ideas, I can examine the 1992 study by Sigurdson and Olson that we cited earlier. While it has some interesting findings in the area of individual differences, it is also fraught with the difficulties and weaknesses inherent in conducting experimental research in a classroom. The purpose of their study was to compare three teaching approaches: one emphasizing meaning, another emphasizing other skills and procedures in mathematics, and the third using a traditional approach. Although their basic problem is worth investigating, we believe that they severely limited the generalizability of their results by using the experimental approach. To attempt for consistency among treatment groups and teachers, they varied seatwork but tried to keep homework, class talk, and questioning the same. This artificially constrains the use of the meaning-treatment methods. It is also unlikely that all of those factors were controlled adequately among several for an experimental study, thereby confounding the results. (In fact, they had to throw out some results because some teachers did not follow the program adequately.) They used a posttest and a retention test composed of multiple-choice questions covering computation, comprehension, and problem-solving questions. All treatment groups took the same test. Again, this is a necessity in an experimental study, but hardly reflective of actual classrooms. REALs use authentic assessment strategies, matching assessment with the objectives and methods. It is unlikely that an actual classroom using a meaning approach would use conventional testing strategies. The experimental nature of the study violates a teaching principle of evaluating in ways that match the ways students are taught. So, although they found some differences among the groups, the generalizability of those findings is limited because of the artificial constraints placed on the teaching and assessment methods.

23.6.2 Media Versus Method

Another major research issue, especially for instructional technologists, is the question of media versus method. Clark (1994) states that instructional methods are confounded with media, and it is instructional methods that influence learning, not the media. He contends that media are simply interchangeable delivery platforms whereby any necessary teaching method can be designed in a variety of media. Clark states that:

> . . . if learning occurs as a result of exposure to any media, the learning is caused by the instructional method embedded in the media presentation. Method is the inclusion of one of a number of possible representations of a cognitive process or strategy that is necessary for learning but which students cannot or will not provide for themselves (p. 26).

I agree with Clark and believe that our instructional technology research needs to focus more on processes and less on media. One need only attend conferences fairly regularly to see that our field runs through fads or favorite media in cycles. At the time of this writing, hypermedia and multimedia are popular applications and foci of research. Yet both are simply kinds of media used to support instructional methods.

Researchers and developers sometimes argue that certain kinds of media encourage different kinds of reasoning. For example, researchers using hypermedia applications sometimes claim that hypermedia affects learners' reasoning and processing activities because of the nonlinear construction of hypermedia applications (Nielsen, 1990). Yet the media are the same used in other applications. If hypermedia or multimedia encourage a specific kind of reasoning, it is because of the methods designed in the program, such as using hypermedia to apply cognitive flexibility theory (Borsook & Higginbotham-Wheat, 1992; Jacobson & Spiro, 1991; Jonassen, Ambruso & Olesen, 1992). Clark

(1994) would contend, then, that cognitive flexibility could be applied equally well to other media, including video, text, or illustrations. If studies that show that a specific medium or set of media attributes cause learning, then they are at the same time confounded because the study has failed to control for instructional method. Instructional method is always present, while a medium or media attributes are surface features that are replaceable.

This is an important issue for instructional technologists because it delineates what is important in a learning environment. Whether a REAL is supported by technology or not is not important. Research that focuses on the use of specific media diverts attention from what is actually important in a REAL, the instructional methods that permit students to take initiative for their own learning within authentic contexts. Clark (1994) describes this as an economic issue:

> The question is critical because if different media or attributes yield similar learning gains and facilitate achievement of necessary performance criteria, then in a design science or an instructional technology, we must always choose the *less expensive* way to achieve a learning goal. I must also form out theories around the underlying structural features of the *shared properties* of the interchangeable variables and not base theory on the irrelevant surface features (p. 22).

23.6.3 Methodology Strategies

Research strategies, then, need to emphasize learning processes. Therefore we need to develop and to find strategies that let us examine the cognitive processes of learning rather than just the products. Below, we describe several strategies worth noting, hopefully to entice you into doing further research into their applicability to your own research programs.

23.6.3.1. Think-Alouds. One strategy gaining increasing use is think-aloud protocols. Ericsson and Simon (1984) demonstrated that protocol analysis can produce detailed, quantifiable, and reproducible data on human thought processes. Think-alouds ask learners to literally think aloud while solving a problem. This illuminates their understanding of concepts and the presence of any misconceptions. Pellegrino et al. (1991), Stoiber (1991), and Palincsar and Klenk (1992) all used some form of think-alouds in the reviews above.

23.6.3.2. Written-Question Generation. Torney-Purta (1990) describes the use of question generation techniques. Torney-Purta asked students to generate four questions dealing with a problem. The questions indicate the depth of understanding and often illuminate cause-and-effect relationships. Students that generate what-if questions usually indicate a deeper understanding of the content because they can wonder about variables and the relationship of one to another.

23.6.3.3. Ranking and Classification Techniques. Another technique used by Torney-Purta (1990) is a ranking or classification task. She asked students to rank items within a group according to a specific dimension and to give reasons for the rankings (combining the think-aloud protocol). Classification indicates depth of understanding of the dimensions used for ranking and can point up misconceptions. Palincsar and Klenk (1992) also used a classification technique to study reciprocal teaching. Students sorted pictures into two piles and talked aloud to explain why one picture belonged with the others. This indicated the kind of dimension (i.e., physical or thematic) that students were using and the depth of understanding related to the text they read.

23.6.3.4. Concept Maps. Robertson (1990) and Dunlap and Grabinger (1992) have shown that concept maps, generated either by students or by computer programs, can also represent the depth of understanding and complexity of understanding of related concepts. They provide a tool for students to compare and analyze their own thinking. The maps could be combined with think-alouds by having students try to explain their own conceptions.

23.6.3.5. Analysis of Recordings. Stoiber (1991) used an individual video-stimulated interview technique. She had students reflect on a videotaped performance to examine their ability to use concepts and understandings to critique the tape. The interviews indicated how creative the students were in applying classroom management techniques.

23.6.3.6. Dependent Measures and Assessment Foci. What do the above strategies aim to measure? In general terms, I present four complexities defined by Torney-Purta (1990). These "complexities" (generalized the author; the original article focused on social studies) define areas in which we hope any REAL is successful. These areas, then, provide assessment goals and emphases for research studies. They suggest dependent measures and assessments to measure the effectiveness of REALs and the growth of students' problem-solving abilities.

1. Students with complex structures should be able to visualize or access a variety of different solutions to a problem. A research study could give students opportunities to explore different options and observe how the thinking of the student changes as a result of the exploration and experimentation.
2. Students with complex knowledge structures can see constraints on the effectiveness of possible solutions. Pellegrino et al. (1991) discovered that students experienced in multiple-step problem solving could identify constraints within the context more easily than students who did not have the same experience. They used think-alouds to monitor student processes.
3. Students with complex scripts as a structure for understanding a domain can see the relevance of potential actions. They can pose questions and hypotheses that represent the depth of the domain. Students who can do this can ask what-if questions and have also developed a sense of experimentation and wonderment.
4. Students with complex structures are able to rank or categorize definable groups along a complex set of dimensions. Learners must indicate depth of understanding in evaluations, and a classification task is good way to visualize that depth.

Torney-Purta's complexities are indications of the effectiveness of REALs in developing problem-solving skills. Ultimately, we must examine student performance with authentic problems both close in and removed from the original learning situation.

23.7 RESEARCH ISSUES AND QUESTIONS

What, then, are some of the issues that need investigation in REALs? In actuality, it is everything. At this stage, nothing has been done too much or too well. However, I consider the following topics particularly important.

23.7.1 Individual Differences

Sigurdson's and Olson's (1992) study raises a question found in other ability research. They found that the students in the top one-third of the class responded almost as well to algorithmic-practice teaching as to meaning teaching. The best students learn in spite of what we do to them. The middle one-third of students responded well to teaching with meaning, while the lowest one-third did not respond well to either of treatment. Can this effect be replicated in other studies? Can low-ability students benefit from REALs, or are REALs only for higher abilities or intelligence levels? If REALs are limited to the higher-ability students, are the methodologies inherent in REALs the reason for successful learning, or is it the ability inherent in the successful students?

23.7.2 Learner Control

Individual differences are closely related to questions of learner control. Learner control is one of the main issues related to teaching students to become intentional learners. They must develop metacognitive skills to make good control decisions. Can we specify those metacognitive skills? What can we do to help students develop those skills? For example, Arnone, Grabowski, and Rynd (1994) found that high-curious primary-age children function better given more learner control than low-curious children. Do the high-curious children possess greater intellectual curiosity or ability? How do they use their curiosity? What do they do differently in terms of learning processes?

23.7.3 Scaffolding and Support

An important part of teaching students to be intentional learners is providing them with the appropriate scaffolding and support to help them move toward more independence. The CTGV (1993) state that:

> We need to carefully explore issues of how best to provide support for comprehension and learning. We suspect that there is a need to consider [interactive media] designs that function as scaffolds rather than always providing an option for full support (p. 78).

We need to identify the skills students need to perform independently to help them develop lifelong learning skills. Yes, we know in general what independent learners do, but we need to break those general skills into operational skills that teachers can work with. Brown (1989, p. 40) asserts that "one of the particularly difficult challenges for research . . . is determining what should be made explicit in teaching and what should be left implicit."

Many of the research strategies described above are aimed at examining reflective processes by making them visible. What can be done to increase students' ability to reflect both on the problem and on their own problem-solving and learning processes? In part, this is related to providing scaffolding and support, for support must go beyond tools and strategies for learning content; it must also include tools and strategies for learning the processes of learning and developing metacognitive awareness.

Research into scaffolding and support should also be directed at teachers. How can developers of REALs support their implementation and adoption in the classroom? Using REALs means radical changes, and it is difficult to make those changes without support. The CTGV is trying out electronic networks and teleconferencing in helping teachers develop the skills necessary to change and to use REALs in the classroom. What tools and strategies do we need to prepare for teachers?

23.7.4 Learning

Learning is still the *raison d'être* for REALs. Williams (1992) suggests that we investigate methods that help students abstract general principles from the study of cases and problems. What can teachers do to help students abstract general principles from context specific learning? She also suggests that we measure not only content-based learning but also improvement in skills related to learning to learn. I must expand our concern from how much students learn to the inclusion of how people learned what they learned. This leads directly to assessment issues.

23.7.5 Assessment

We should assess learning in ways that are authentic, manageable, and supported by parents and administrations. Assessment strategies must examine what content people learned, the strategies employed in learning, and what students can do with the knowledge. Williams (1992) describes the following problems with current assessment strategies: First, students are often assessed on skills different from the ones they are taught; second, written tests of problem-solving performance are time consuming to administer and score; and third, assessment of problem-solving performance tends to be subjective. I made a number of suggestions related to assessment in the first half of the paper, but those options are probably only the beginning of new ways of assessing learning. Research needs to be conducted on all of those options to identify the most efficient and effective ways to apply them.

Peer assessment is also an area needing more research. Peer assessment is another way for students to assume more responsibility for their learning and for each other's learning within the learning community. Rushton, Ramsey, and Rada (1993) studied a group of 32 undergraduate students who participated in a peer assessment exercise. Contrary to expectations, the marks awarded by the peers were remarkably similar to those awarded by the tutors. Despite this, the majority of the students were extremely skeptical of peer assessment, preferring traditional teacher-based assessment. Rushton, Ramsey, and Rada's results need to be replicated, and we need to find ways to increase student assessment.

23.7.6 Technology and Research

You may have noticed something conspicuous in its absence, especially in a book on research in instructional technology—the absence of any discussion about technology in its hardware form. If you go back and look at the definition of REALs, you won't even find the word *technology* in the definition. Although we argued earlier that research needs to focus on methods and not media, this does not preclude research into technology to determine its potential usefulness and ways to integrate instructional methods within technology. (Part II of this text deals with a number of hard technologies and media-related research.) REALs are gaining more attention because technology has developed to an extent that helps teachers give more time to individuals, and because it provides tools to help learners become more independent. In the past, AV delivery systems depended on discrete audio and visual channels that transmitted separate message content. These constraints encouraged people to think about their designs as tools, either audio or video (Allen, 1994). Allen states that thinking in terms of information channels is artificial:

> Humans in unmediated environments do not seem to frame their perceptions or actions in terms of information channels; rather, they appear to organize both their perception and their reasoning in terms of objects and agents of action. In spite of separate pathways for sensory information dictated by different cranial nerves for vision, olfaction, and audition, our capabilities of perception, memory, and language integrate across sensory modalities and our minds attend to avenues for exploration and action (p. 34).

Therefore, the human-machine relationship is more than discrete sensory inputs. The machines are tools that facilitate processes. So, how can we design machines to help people learn and think? Does this mean that machines need to replicate human processes or that machines support processes? Can we use machines to help make the thinking and learning processes visible and more accessible? Allen (1994) says that "I need to think more about how to design media systems as livable environments, and this will require much rethinking about what it means for humans to be intimate with their media machines" (p. 34).

Besides the nature of technology and its interfaces, we need to look at specific tool uses for technology. (For a much more detailed treatment of this topic, see Chapter 25.) Lajoie (1993) describes four uses for cognitive tools in learning environments: (1) to support cognitive processes, (2) to share the cognitive load by providing support for lower-level cognitive skills, (3) to allow learners to engage in learning activities normally out of reach, and (4) to allow learners to generate and test hypotheses. These uses are related to scaffolding and metacognitive issues, and again emphasize the importance of working with technology in the context of a strategy rather than as the cause of learning.

23.7.7 The Process of Change

The implementation of REALs means radical change in most classrooms and schools. Change is always difficult, even when supported strongly by the parties involved. (Chapter 37 discusses diffusion and adoption of educational technology.) Kirsner and Bethell (1992) describe one high school teacher's attempt to change her mathematics teaching in ways that are consistent with the National Council of Teachers of Mathematics. Although they found that a professional development school provided a relatively supportive environment, the teacher would have benefited from more consistent support as she struggled with pedagogical and content-related issues. Schools are set up to support one style of teaching. "Calls for change of any kind are seen as impositions or disturbances to be quelled as soon as possible, as unreasonable attempts to change the rules in the middle of the game" (Hodas, 1993, p. 7). In fact, Van Haneghan (1992) lists five reasons for failure or difficulties in implementing REAL strategies, and each can be dealt with through effective change management processes:

1. Curriculum developers fail to realize that their curricula involve more than materials. They must include methods and resources, too. Teachers have little time, so we must provide them with as many tools as possible to facilitate the change to a REAL classroom.
2. Curriculum developers fail to adequately train and provide support to teachers when a curriculum becomes widespread. Many teachers are interested in new techniques but need strategies and support to be successful. They must have colleagues whom they can talk to, either personally or electronically.
3. Curriculum developers fail to provide ways to integrate the program into the curricular goals of particular schools and teachers. Developers must recognize that their curriculum is not isolated but must fit within a system. Support must be provided to fit the new curriculum within the "old" school.
4. Assessment is a long-neglected issue, and developers fail to develop adequate assessment tools. Developers must not expect teachers to automatically develop

new assessment strategies. Teachers need new ideas and tools for this topic, too.

5. Curriculum developers assume that curricula are developed in a top-down manner. They often dictate to teachers what they should or should not do. But teachers are more likely to adopt something from a grass roots movement than top-down fiat. They need to see the benefit and buy into the new program.

What can we do to support teachers who wish to try another style? What strategies can we provide teachers? How can we gain student, collegial, administrative, and parental support? Recall, too, that students are probably the most important group involved in this change, especially older students in high schools and colleges. These older students have learned to "play the game" with years of practice. The further they advance in education, the more successful they are at the game. Our own experiences in adopting REALs have shown significant initial resistance from students. They have to learn a new set of rules. Responsibility is risky, and they need to know that the risk is not going to be punished. This is an area of research interest that needs much work but is often not pursued by our technologically oriented field. I need to expand our field and promote research into the instructional change process.

23.8 CONCLUSION

In this chapter, I have defined REALs, looked at research into the effectiveness of REALs, and discussed several issues awaiting research. There have been a number of several recurring themes in our discussion of REALs. First is the importance of transfer. REALs are used to facilitate transfer to new situations and to meet the complaint from employers and schools that students cannot use what they know. Second is the importance of context in learning. Decontextualized learning causes inert knowledge. Even though a new context may be different from the context in which students learned, it is more likely that the students will try to apply what they know. They may be wrong, but what they've learned is the necessity for trying new things and analyzing what is right or wrong. They have created indexes that relate to real problems, not abstract, meaningless problems. Fourth is the importance of self-reflection and metacognitive awareness. A lifelong learner is by definition reflective and metacognitively aware. Lifelong learners try alternatives, look for multiple solutions, and, most importantly, try to optimize their solutions. They look for alternatives rather than a single way for solving problems. Finally, the attributes of REALs are interdependent and symbiotic. A REAL is a set of interlocking strategies designed to promote the learning of content and learning. Some manifestations of REALs may emphasize one attribute over another, but you will find evidence of each attribute in cognitive flexibility, anchored instruction, problem-based learning, intentional learning, reciprocal teaching, and so on.

Rich environments for active learning are one way of looking at and applying constructivist principles to learning. REALs are one attempt to bring together thoughts, ideas, and theories in a way that will help teachers at all levels develop classroom environments that foster higher-level thinking skills, especially reflection, problem solving, flexible thinking, and creativity. I owe our students a return on their investments. One way to make that return is by adopting methods and roles that help our students not only learn content but also learn skills that will make them lifelong learners.

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