Preparing Teachers for a Changing World

What Teachers Should Learn and Be Able to Do

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CHAPTER TWO

Theories of Learning and Their Roles in Teaching

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A Disturbing Discovery

It was one o'clock in the morning. Paul Nelson had spent the last eight hours grading final exams from the students in his high school astronomy classes. This was his first year as a teacher and he was exhausted and distressed because most of the essays showed clear evidence of misunderstandings on the part of the students.

The majority of the students wrote that summer temperatures were warmer than winter temperatures because the earth was closer to the sun in the summer. This was a false assumption that Paul had discussed several times in class. He had shown his students a model of the solar system and explained that summers were hotter than winters because of changes in the angle of the earth and the sun—not the distance of the earth from the sun. He knew he had mentioned this point at least three different times.

Paul wondered what had gone wrong. Were the students less capable than he had assumed? Were they not paying attention even though they seemed to be interested in the topic of astronomy? Was there something about having to put their thoughts into writing that caused them to do poorly? Given that he would be teaching the course the next year, was there something he should do differently? And if so, what and why?

Variations on the preceding scene occur again and again among K–12 teachers, college professors, people involved in business training, and others. They often feel that information was presented with great care and clarity and are stunned when students fail to perform as well as they had expected. Was it their fault, the students' fault, the curriculum's fault—some portion of all

of these? And what is needed to help everyone be more successful the next time around?

The questions asked by Paul Nelson and other educators who experience similar difficulties involve questions about the nature of human learning. We all make assumptions about learning whether we realize it or not. We make assumptions about what is important for people to learn (understanding the earth's role in the solar system—including why it is warm in the summer—seems to qualify as worth knowing), about who can learn well and why, and about effective strategies for enhancing our own learning and that of helping others. Peoples' assumptions about learning can be considered to be tacit (unconscious) theories that affect their behavior, but tacit theories typically remain unexamined. By making tacit theories explicit, people can think more critically about them. This allows us to improve upon ideas and assumptions that may be partially true but far from complete. In cases like the one experienced by Paul Nelson, explicit theories of learning can help educators rethink their teaching processes. This is what people mean when they say: "There is nothing as practical as a good theory." The goal of this chapter is to provide a way of thinking about learning that can help educators improve their efforts to teach.

THE *HOW PEOPLE LEARN* FRAMEWORK AS A WAY TO ORGANIZE THINKING

We organize our discussion around the *How People Learn* (HPL) framework (see Figure 1.7 in Chapter One) that was used by a National Academy of Science Committee to organize what is known about learning and teaching (National Research Council, 2000). The framework's four components can be used to highlight areas where we all tend to have "mini theories" (often tacit) about learning and teaching. For example, we all make assumptions about

- What should be taught, why it is important, and how this knowledge should be organized (knowledge-centeredness)
- Who learns, how, and why (learner-centeredness)
- What kinds of classroom, school, and school-community environments enhance learning (community-centeredness), and
- What kinds of evidence for learning students, teachers, parents, and others can use to see if effective learning is really occurring (assessment-centeredness).

Teachers must learn to balance and integrate all four components of the HPL framework if they are to teach effectively. We begin by discussing each component separately and then explore the balancing act that effective teachers must continually orchestrate to help all students succeed.

Knowledge-Centeredness

The knowledge-centered aspect of the HPL framework seems obvious at first glance—so obvious that it hardly requires discussion. People often say, "Of course, learning involves knowledge (and skills, which we here assume are also a part of this knowledge). What else is new?" On second glance, however, issues about the nature of knowledge are extremely important and far from obvious. For example, it is easy to fall into the trap of assuming that schools should teach what we learned when we grew up. However, the world has changed and different kinds of skills and knowledge are required for successful and productive lives in the twenty-first century. People also have differing views of the purposes of education and hence the kinds of things that are worth knowing. The chapter on curriculum (Chapter Five) takes a special look at these issues. Among the points it discusses is how technology is changing our world and how people need to learn to use it to succeed.

Understanding the Nature of Expertise

Research in the learning sciences has explored the nature of the skills and knowledge that underlie expert performances, and this research is important for thinking about the design of effective curricula. For example, we know that experts notice features of problems and situations that may escape the attention of novices (see, for example, Chase and Simon, 1973; Chi, Feltovitch, and Glasser, 1981; de Groot, 1965). They therefore "start problem solving at a higher place" than novices (de Groot, 1965). This has a number of implications for teaching, including the need for teachers to frame what learners should pay attention to. For example, when teachers attempt to teach through video, field trips, internships, and other experiences in which students are expected to learn by observation and participation, teachers need to help students bring a mental organization to the learning experience. Consider videos: when teacher educators show them to teachers, or teachers show them to students, many features in the videos will be obvious to experts yet go unnoticed by novices unless the features are pointed out and discussed.

In addition to "noticing," problem solving and memory are strongly affected by the knowledge and skills available to the experts. For example, de Groot showed master chess players a five-second glimpse of a chess game in progress and then removed it from sight and asked them to reproduce what they had seen by using chess pieces that had been given them. The experts did extremely well at this task—much better than people less experienced in chess. One might conclude the experts did better because they are "more intelligent" or "have

better memories." But it turns out that their abilities to remember are closely linked with their knowledge of chess.

One way that people tested this idea was to *randomly* place chess pieces on a chessboard (Chase and Simon, 1973). Under these conditions chess experts' knowledge is not nearly as useful because they are unable to detect meaningful patterns or "chunks" of information. And indeed, under random conditions, differences in memory between chess masters and less experienced players disappeared (see Chase and Simon, 1973).

An interesting variation on this experiment was conducted by Chi (1978). She compared the memory performances of college students and ten-year-old students who played a lot of chess. (The college students were not chess players.) When she asked participants in her experiment to remember strings of numbers, the college students did better than the ten-year-olds. However, when asked to remember parts of a chess game, the memory "abilities" reversed and the ten-year-olds did a much better job.

An Illustration of Expertise and Remembering. The studies about chess are among the many that show that peoples' expertise in an area affects their ability to remember and solve problems (National Research Council, 2000). One important component of these studies involves the amount of effort required to learn and remember new information. Sometimes we are able to learn almost "effortlessly"; we are able to rely on processes that are relatively automatic. At other times our learning depends on explicit strategies that are much more effortful (for example, see Hasher and Zacks, 1979). The degree to which a memory task fits our current levels of expertise can have strong effects on the amount of effort needed for processing. A demonstration that illustrates different effects of effortless processing on memory (depending on what we as learners already know) is provided in "Memory, Expertise, and Effortless Processing I."

Memory, Expertise, and Effortless Processing I

Differences between effortful and effortless processes are illustrated by the following demonstration experiment. In this exercise, please spend no more than four seconds reading each of the following sentences, and read each one only once. Most importantly, try not to use any fancy strategies such as generating elaborate images, rehearsing to yourself, and so forth. These are effortful strategies. Try to react to each sentence as effortlessly as you can.

John walked on the roof.
Bill picked up the egg.
Pete hid the axe.
Jim flew the kite.
Frank flipped the switch.
Alfred built a boat.
Sam hit his head on the ceiling.

Adam quit his job.
Jay fixed the sail.
Ted wrote the play.

Now try to answer the following questions without looking back at the preceding sentences.

Who built the boat?
Who picked up the egg?
Who walked on the roof?
Who quit his job?
Who flew the kite?
Who fixed the sail?
Who hit his head on the ceiling?
Who wrote the play?
Who flipped the switch?
Who hid the axe?

Most people have a very difficult time remembering who did what despite the fact that each statement was comprehensible. If you really approached these sentences in a relatively "effortless" manner, you probably could remember only two or three at most. To remember these sentences you would have had to use very effortful, sophisticated strategies such as thinking of someone you know with a particular name (for example, a friend of yours named John) and making an image of him walking on the roof.

Sentences similar to those presented earlier become much easier to remember if our knowledge base can do much of the work for us. As an illustration, spend approximately four seconds reading each of the following sentences. As in the earlier task, do not attempt to use any effortful, sophisticated strategies. Instead, react to each sentence as effortlessly as you can.

Santa Claus walked on the roof.
The Easter Bunny picked up the egg.
George Washington hid the axe.
Benjamin Franklin flew the kite.
Thomas Edison flipped the switch.
Noah built a boat.
Wilt Chamberlain hit his head on the ceiling.
Richard Nixon quit his job.
Christopher Columbus fixed the sail.
William Shakespeare wrote the play.

Now answer the following questions without looking back at the list.

Who built the boat?
Who picked up the egg?
Who walked on the roof?
Who quit his job?
Who flew the kite?

Who fixed the sail?
Who hit his head on the ceiling?
Who wrote the play?
Who flipped the switch?
Who hid the axe?

This demonstration experiment has been used many times (Bransford and Stein, 1993). Invariably, it is much easier to remember the second set of materials (about Nixon, Columbus, and so forth) than the first (about John, Robert, and so on). The second set of materials is designed to activate knowledge that, without much effort, permits a number of elaborations that make the problem of remembering quite easy to solve. For example, you have probably not heard the exact statement that "George Washington hid the axe," but your knowledge of George Washington is rich enough to easily generate elaborations such as, "it was the axe used to chop down the cherry tree—a tree he was not supposed to chop down." Similarly, for the sentence "Richard Nixon quit his job," you probably found yourself thinking that the job was the presidency, that he was forced to resign, and so forth. Because of the richness of your knowledge, a number of elaborations almost automatically come to mind.

There may have been a few people in the "named" list whom you didn't know. Younger generations often do not know Wilt Chamberlain, for example (a star basketball center). If you didn't know some of the names, you probably noticed that it made remembering more difficult.

Source: The IDEAL Problem Solver, 2nd edition by John D. Bransford and Barry Stein. © 1984, 1998 by W. H. Freeman and Company. Used with permission.

Expertise and Knowledge Organization. Research on expertise also provides important information on how knowledge should be organized. Experts' knowledge is much more than a list of disconnected facts about their disciplines. Instead, their knowledge is connected and organized around important ideas of their disciplines. This organization of knowledge helps experts know when, why, and how aspects of their vast repertoire of knowledge and skills are relevant in any particular situation (see Bransford, Brown, and Cocking, 1999; Chapter Two). Knowledge organization especially affects how information is retrieved.

Bruner (1960/1977), one of the pioneers in cognitive and developmental psychology, makes the following argument about knowledge organization:

> The curriculum of a subject should be determined by the most fundamental understanding that can be achieved of the underlying principles that give structure to a subject. Teaching specific topics or skills without making clear their context in the broader fundamental structure of a field of knowledge is uneconomical . . . An understanding of fundamental principles and ideas appears to be the main road to adequate transfer of training. To understand something as a specific instance of a more general case—which is what understanding a more fundamental structure means—is to have learned not only a specific thing but also a model for understanding other things like it that one may encounter. (pp. 25 and 31)

Courses are often organized in ways that fail to develop the kinds of connected knowledge structures that support activities such as effective reasoning and problem solving. For example, texts often present lists of topics and facts in a manner that has been described as "a mile wide and an inch deep" (for example, see National Research Council, 2000). This is very different from focusing on the "enduring ideas of a discipline." In agreement with Bruner, Wiggins and McTighe (1998) argue that the knowledge to be taught should be prioritized into categories that range from "enduring ideas of the discipline" to "important things to know and be able to do" to "ideas worth mentioning." Thinking through these issues and coming up with a set of "enduring connected ideas" is an extremely important aspect of educational design.

The organization of peoples' knowledge affects process skills such as their abilities to think and solve problems. Links between knowledge organization and process skills (for example, evaluating and designing experiments) are illustrated in the experiment described in "Knowledge Organization and Problem Solving."

Knowledge Organization and Problem Solving

A group of college students received a challenge over the Internet before coming to class. The responses to the challenge help illustrate relationships between knowledge organization and problem solving. The challenge they received is described in the following section:

"As a group of biologists compare data from across the world, they note that frogs seem to be disappearing in an alarming number of places. This deeply concerns them, because the frogs may well be an indicator species for environmental changes that could hurt us all. The biologists consider a number of hypotheses about the frogs' disappearance. One is that too much ultraviolet light is getting through the ozone layer.

"One group of biologists decides to test the ultraviolet light hypotheses. They use five different species of frogs, with an equal number of male and female. Half of the frogs receive constant doses of ultraviolet light for a period of four months—this is the experimental group. The other half of the frogs—the control group—are protected so they receive no ultraviolet light.

"At the end of the four months, the biologists find that there is no difference in the death rates between the frogs in the experimental and control groups. This suggests that ultraviolet light is probably not the cause of the frog's demise.

"What do you think about the biologist's experiments and conclusions? Are there questions you would want to ask before accepting their conclusions? Are there new experiments that you would want to propose?"

Students responded to the challenge by posting written answers on the Internet before coming to class. They noted a number of good points about the experiment; for example, that it involved an experimental-control design that involved several different species of frogs, used stratified random sampling, and so forth. Students also raised a number of concerns such as, "Maybe the doses of ultraviolet light that were used were too weak"; "Maybe the light was provided for too short a time" (that is, only four months); "Maybe the experimenters didn't wait long enough to see the effects of the ultraviolet light, so maybe they should have looked at difference in illness between the two groups rather than compare the death rates." Not a single student questioned the fact that only adult frogs were used in the experiment (the multimedia materials that were part of the challenge that students viewed on the Internet showed clearly that the frogs were all adults). When the students arrived in class (remember that they had answered the challenge on the Internet before attending class), the instructor asked whether a flaw may have been to use only adult frogs rather than attempt to explore the effects of ultraviolet light on potentially vulnerable points in the frogs' life cycle. Every student immediately realized that the answer was "yes," and they stated they had all studied life cycles. However, they had learned about life cycles as isolated exercises (for example, they had been asked to memorize the stages of the life cycle of a fly or mosquito) and had never connected this information to larger questions like the survival of a species. As a consequence, the idea of life cycles had never occurred to them in the context of attempting to solve the preceding frog problem. To paraphrase Whitehead (1929), knowledge that was potentially important for exploring the frog problem had remained "inert."

The suggestion by Bruner (1960/1977) that was discussed earlier is highly relevant in this context; namely, that "Teaching specific topics or skills without making clear their context in the broader fundamental structure of a field of knowledge is uneconomical . . . An understanding of fundamental principles and ideas appears to be the main road to adequate transfer of training" (p. 25). The students in the class had all learned about life cycles, but their teachers and texts did not make clear the importance of this information in the broader structure of the field of knowledge.

The vignette presented at the beginning of this chapter (about the astronomy teacher who was dismayed that his students still believed that summer on earth was caused by its distance from the sun) is also relevant in this context. If explicitly reminded, students may have been able to remember seeing a demonstration of tilted orbits. Nevertheless, their thinking about the seasons was probably driven by other knowledge that they had available for them. For example, many experiences support the idea that distance from a heat source affects temperature. The closer we stand to radiators, stoves, fireplaces, and other heat sources, the greater the heat (National Research Council, in press).

Interestingly, there are also experiences in which we can manipulate the intensity of heat by changing the angle of a heat source—by pointing a hair dryer on one's head at different angles, for example. But without the ability to carefully control distance from the head or the tools to measure small changes in temperature (and without some guidance that helps people think to do this experiment in the first place), the relationship between heat and angle of the heat source can easily be missed.

Expertise and Teaching

Information about relationships between expert knowledge and teaching abilities is especially important for teachers to understand. At one level, teachers must have knowledge of their disciplines to teach effectively. Consider knowledge about elementary physics and simple machines (for example, levers, pulleys). Teachers who know a great deal about this topic can create classroom environments where students get to experiment with using simple machines and can ask the teacher questions about why certain things happened (for example, "Why did this way of using the lever work better than that way?"). Teachers need considerable knowledge in order to answer a wide range of questions that arise from the problems that students confront. Teachers who don't understand much physics will often have difficulty answering these questions. They may therefore be much more inclined to follow only the restricted set of activities in the textbook, where answers are provided in the teachers' edition of the text.

There is also a downside to having a great deal of knowledge about one's subject matter. Sometimes, the information becomes so intuitive that experts lose sight of what it was like to be a novice. In his studies with chess masters, de Groot (1965) notes how masters were often incredulous that lesser experienced players could not see "obvious" features of the game board that were "right before their eyes" and signaled clearly what the next move should be.

Nathan and colleagues (Nathan, Koedinger, and Alibali, 2001; Nathan and Petrosino, 2003) use the term *expert blind spots* to refer to downsides of content expertise. Experts are often blind to the fact that much of their knowledge of their subject matter has moved from explicit to tacit and hence can easily be skipped over in instruction. For example, experts in physics and engineering may not realize that they are failing to communicate all the information necessary to help novices learn to construct their own free body diagrams (Brophy, 2001). The reason is that many decisions are so intuitive that the professors don't even realize that they are part of their repertoire.

Shulman (1987) explains that effective teachers need to develop "pedagogical content knowledge" that goes well beyond the content knowledge of a discipline (see also Hestenes, 1987). It includes an understanding of how novices typically struggle as they attempt to master a domain and an understanding of strategies for helping them learn. Chapter Six in this volume explores the concept of pedagogical content knowledge in considerable depth.

Adaptive Expertise

An especially important analysis of expertise focuses on differences between "routine experts" and "adaptive experts" (for example, Hatano and Inagaki, 1986; Hatano and Osura, 2003). Both routine experts and adaptive experts continue to learn throughout their lifetimes. Routine experts develop a core set of competencies that they apply throughout their lives with greater and greater efficiency. In contrast, adaptive experts are much more likely to change their core competencies and continually expand the breadth and depth of their expertise. This restructuring of core ideas, beliefs, and competencies may reduce their efficiency in the short run but make them more flexible in the long run. These processes of restructuring often have emotional consequences that accompany realizations that cherished beliefs and practices need to be changed.

Figure 2.1 provides a characterization of adaptive expertise that is relevant for thinking about issues of learning and teaching (Schwartz, Bransford, and Sears, in press, in conjunction with the LIFE Center).

Schwartz and others note that the horizontal dimension in Figure 2.1 emphasizes efficiency; the vertical dimension emphasizes innovation. Sometimes these two dimensions are characterized as mutually exclusive ends of continuum (for example, high- and low-road transfer, Perkins and Salomon, 1989). However, because there are different processes involved, they are not necessarily exclusive of one another. Adaptive experts, for example, are presumably high on both dimensions (for example, Gentner and others, 1997; Hatano and Inagaki, 1986; Wineburg, 1998). Adaptive expertise is discussed as a "gold standard for learning" in *How People Learn* (National Research Council, 2000).

Schwartz and others (in press) note that "the horizontal dimension in Figure 2.1 is efficiency. People who are high on efficiency can rapidly retrieve and accurately apply appropriate knowledge and skills to solve a problem or understand an explanation. Examples include experts who have a great deal of

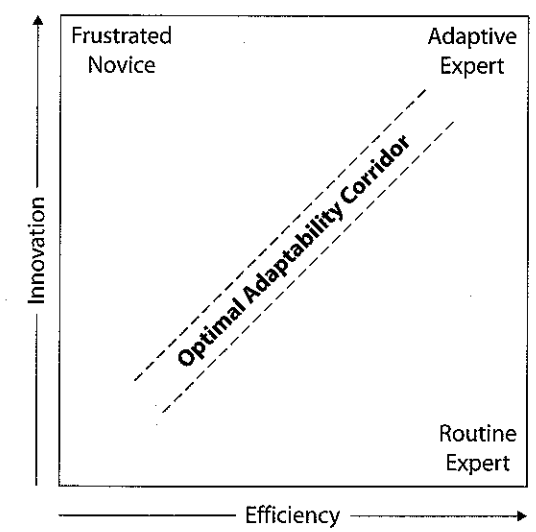

Figure 2.1 The Dimensions of Adaptive Expertise.

experience with certain types of problems; for example, doctors who have seen many instances of diseases in many different people or who have frequently performed a particular type of surgery. They can diagnose and treat a new patient quickly and effectively. Many instructional strategies are designed to develop the kinds of efficiency that enable people to act with fluency." Schwartz and colleagues (in press) also note the following:

> Researchers who study both people and organizations have learned a great deal about promoting efficiency. At a general level, probably the best way to be efficient is to practice at tasks and gain experiences with important classes and components of problems so that they become "routine" and easy to solve later. The best way to ensure transfer is to "teach for it" so that the problems people encounter on a test or in an everyday environment can be solved with high frequency because they are quite close to what has been learned previously. Transfer problems essentially disappear if we teach in contexts where people need to perform, and if we arrange experiences and environments so that the correct behaviors are driven by the environment.

There are ways to practice solving problems that are excellent from an efficiency perspective. Appropriate kinds of practice help people turn nonroutine, difficult-to-solve problems into routine problems that can be solved quickly and easily. Phrased another way, efficiency-oriented practice is often about "problem elimination" rather than about in-depth, sustained problem solving. A problem is typically defined as a gap or barrier between a goal state and one's present state (see, for example, Bransford and Stein, 1993; Hayes, 1990; Newell and Simon, 1972). By preparing people so that the problems they will face in life are essentially routine problems—or at worst very "near transfer" problems—the gap between goal states and present states is either eliminated or made to be very small. This allows people to perform quite effectively.

Schwartz and others (in press) proceed to note that all of this works well *provided* the environments for which we are preparing people are stable. However, people like Fullan (2001) and Valli (1996) argue that we live in a "whitewater world" where change is the norm and not the exception. Because efficiency is so emphasized in our time-limited society, it tends to take over as a prime way to assess progress. But, there are also potential downsides of an overemphasis on efficiency. For example, studies show that efficiency can often produce "functionally fixed" behaviors that are problematic in new situations (see, for example, Luchins, 1942). Similarly, Hatano and Inagaki (1986) discuss "routine experts" who become very good at solving particular sets of problems but do not continue to learn throughout their lifetimes (except in the sense of becoming even more efficient at their old routines). These potential downsides of an overemphasis on efficiency, especially in the face of change, make it especially important to attempt to reconceptualize learning and transfer as something more than the ability to apply previously acquired skills and schemas efficiently

for routine problem solving. The argument is not to eliminate efficiency but to complement it so that people can adapt optimally.

Schwartz and others (in press) note that the vertical dimension illustrated in Figure 2.1 is innovation. It involves a movement away from efficiency, at least temporarily. It often requires the ability to "unlearn" previous routines (for example, unlearning how to type with two fingers in order to move to a new level of typing efficiency). It also includes the ability to "let go" of previously held beliefs and tolerate the ambiguity of having to rethink one's perspective. The study of history experts versus college students that was mentioned earlier (Wineburg, 1998) provides a good illustration of the need to resist efficient explanations and take the time to explore ideas more carefully. Instructional strategies designed to facilitate innovation are quite different from those that merely facilitate efficiency.

The importance of resisting one's initial ideas about a problem or challenge was discussed by Land, inventor of the Polaroid Land camera. With tongue in cheek, he described the processes of innovation (and the insights that precede them) as involving "the sudden cessation of stupidity." The "stupidity" comes from one's initial framing of problems—framings that contain assumptions that "put people in a box," or more technically, constrained the problem spaces within which they work (see, for example, Bransford and Stein, 1993; Hayes, 1990; Newell and Simon, 1972; Wineburg, 1998).

For educators, Figure 2.1 becomes especially useful when we ask how we can move people along both of its dimensions. Movement along one dimension alone is unlikely to support the development of adaptive expertise. Training dedicated to high efficiency can restrict transfer to highly similar situations. On the other hand, opportunities to engage in general, content-free skills of critical thinking or problem solving appear to provide a set of flexible "weak methods" (Newell and Simon, 1972) that are too inefficient for the large problem spaces found in many real-world tasks.

Researchers have conjectured that people will benefit most from learning opportunities that balance the two dimensions by remaining within the "optimal adaptability corridor" or OAC (Schwartz and others, in press). For example, children who receive nothing but efficiency-oriented computation training in mathematics may well become speedy at performing a specific routine, but this kind of experience will lead to limited capabilities in the face of new problems. Balanced instruction would include opportunities to learn with understanding and develop students' own mathematical conjectures *as well as* become efficient at computation. Instruction that balances efficiency and innovation should also include opportunities to experiment with ideas and, in the process, experience the need to change them. These kinds of experiences often require opportunities to interact actively with artifacts and people to discover inconsistencies and preconceptions that need further refinement. It is useful to consider when and how the instructional approaches discussed in this volume fit within the OAC.

Learner-Centeredness

The learner-centered lens of the HPL framework overlaps with knowledge-centeredness (for example, the idea of "pedagogical content knowledge" provides one such overlap), but the learner-centered lens specifically reminds us to think about learners rather than only about subject matter. When students enter our classrooms we can't help making assumptions about them. Some may sit straight in their desks and write down everything we say. Others may doodle, sprawl, or look out the window as we talk. Some may use language (for example, "I ain't got any") that can easily be misinterpreted as a sign of "poor upbringing" and perhaps "poor learning abilities." Assumptions about the capabilities of students often become "self-fulfilling prophesies" that affect how teachers interact with the students and hence how well they learn.

Chapters Three and Four in this section provide important insights into the complex task of understanding our learners. Chapter Three discusses theories of development and how they impact teaching and learning. Chapter Four discusses theories of language and how language usage (for example, saying "ain't") can act as a "marker" that inappropriately dooms some students to failure in their teachers' minds. Many of the other chapters in this volume also deal with issues of understanding learners and engaging culturally relevant teaching. This includes learning to build on students' strengths rather than simply seeing weaknesses. Several important aspects of being learner-centered are discussed in the following section.

Understanding the Constructive Nature of Knowing

One approach to thinking about learners is to imagine giving them pretests and then marveling at how much they *don't* know about the skills or topics we are teaching. If our focus is primarily on what learners don't know, we'll find lots of evidence that they indeed have lots to learn.

A different approach to understanding learners was emphasized by the famous Swiss psychologist Jean Piaget. He argued that children of all ages were active explorers of their worlds. The complexity of what they could understand was affected by what they already knew and their developmental levels (explained more in Chapter Three). Nevertheless, an important implication of his findings was that even young children were active learners who explored expectations about the world and how it worked. Piaget's theory emphasized the *constructive nature of knowing*. This refers to the idea that we all actively attempt to interpret our world based on our existing skills, knowledge, and developmental levels. Looking at the processes by which students actively attempt to learn is very different from simply testing them on facts or skills and seeing what they don't (for the moment) know.

The constructive nature of knowing is nicely illustrated in the children's story, *Fish is Fish,* by Leo Lionni (1970). *Fish is Fish* is the story of a fish who is interested in learning about what happens on land, but it cannot explore land because it can only breathe in water. It befriends a tadpole, who grows into a frog and eventually goes onto the land. The frog returns to the pond a few weeks later and describes the things it has seen like birds, cows, and people. As the fish listens to the frog's descriptions, he imagines each one to be fish-like. People are imagined to be fish who walk on their tailfins; birds are fish with wings; cows are fish with udders. This story illustrates both the creative opportunities and dangers inherent in the fact that people construct new knowledge based on their current knowledge. In Piaget's terms, the fish *assimilated* the information provided by the frog to its existing knowledge structures. In contrast to processes of assimilation are processes of *accommodation*. Here one changes a core belief or concept when confronted with evidence that prompts such as change.

Studies by Vosniado and Brewer illustrate *Fish is Fish*-style assimilation in the context of young children's thinking about the earth. They worked with children who believed that the earth is flat (because this fit their experiences) and attempted to help them understand that, in fact, it is spherical. When told it is round, children often pictured the earth as a pancake rather than as a sphere (Vosniadou and Brewer, 1989). If they were then told that it is round like a sphere, they interpreted the new information about a spherical earth within their flat-earth view by picturing a pancake-like flat surface inside or on top of a sphere, with humans standing on top of the pancake. The model of the earth that they had developed—and that helped them explain how they could stand or walk upon its surface—did not fit the model of a spherical earth. Like *Fish is Fish,* everything the children heard was incorporated into their preexisting views.

Fish is Fish is relevant not only for young children, but for learners of all ages. For example, college students often have developed beliefs about physical and biological phenomena that fit their experiences but do not fit scientific accounts of these phenomena. These preconceptions must be addressed in order for them to change their beliefs (see, for example, Confrey, 1990; Mestre, 1994; Minstrell, 1989; Redish, 1996). It is important to note that constructivism is a theory of knowing, not a theory of teaching. In particular, adopting a constructivist theory of knowing does not imply that all learning should be discovery oriented and that direct instruction should always be avoided (see, for example, National Research Council, 2000; Schwartz and Bransford, 1998). Instead, it implies that teachers must take account of students' prior conceptions in designing instruction, because these will influence what students learn—for good or for ill—whether or not the teacher is aware of them. The concept of "constructivism" is frequently misunderstood—analogous to the fish's understanding of birds, cows, and people.

Connecting to Students' Existing Knowledge. The *Fish is Fish* story illustrates how previously acquired knowledge can lead people to understand in ways that differ from what others intended. Another aspect of being learning-centered is to understand that previously acquired knowledge can also provide a powerful boost for new learning. Consider the statement: "The haystack was important because the cloth ripped." Most people actively attempt to make sense of the statement but have difficulty understanding it. Now consider the same sentence again but in the context of information about a "parachute." For most people, this provides a clue that allows them to construct a meaningful interpretation of the sentence. If you think about your interpretation, you probably made assumptions about a person using the parachute who jumped from a plane, about that person landing on the haystack, and so forth. None of this information was mentioned in the sentence but it didn't need to be. You supplied it based on your existing knowledge of the world (see, for example, Bransford and Johnson, 1972; Buhler, 1908).

Ideally, what is taught in school builds upon and connects with students' previous experiences, but this is not always the case. A story written in 1944 by Stephen Corey provides an informative look at one example of such disconnects. Entitled "Poor Scholar's Soliloquy," the article is written from the perspective of an imaginary student (we'll call him Bob—the "problem student") who is not very good in school and has had to repeat the seventh grade. Many would write Bob off as having a low aptitude for learning. But when you examine what Bob is capable of achieving outside of school, you develop a very different impression of his abilities.

Part of the soliloquy describes teachers' concerns that one of the reasons Bob is a problem student is that he is not a good reader. He can decode, but he doesn't read the kind of books teachers value. Bob's favorite books include *Popular Science*, the *Mechanical Encyclopedia*, and the Sears and Wards catalogues. Bob uses his books to pursue meaningful goals. He says, "I don't just sit down and read them through like they make us do in school. I use my books when I want to find something out, like whenever Mom buys anything second hand I look it up in Sears or Wards first and tell her if she's getting stung or not."

Later on, Bob explains the trouble he had memorizing the names of the presidents. He knew some of them, like Washington and Jefferson, but there were thirty altogether and he never did get them all straight. From this information, one might conclude that he has a poor memory. Yet Bob also talks about the three trucks his uncle owns and can describe the horsepower and number of forward and backward gears of twenty-six different American trucks, many of them diesels. Then he says, "It's funny how that Diesel works. I started to tell my teacher about it last Wednesday in science class when the pump we were using to make a vacuum in a bell jar got hot, but she said she didn't see what a Diesel engine had to do with our experiment on air pressure so I just kept still. The kids seemed interested, though."

Bob also discusses his inability to do the kinds of word problems found in his textbooks. Yet he helps his uncle make all kinds of complex plans when they travel together. He talks about the bills and letters he sends to the farmers whose livestock his uncle hauls and about how he made only three mistakes in his last seventeen letters—all of them commas. Then he says, "I wish I could write school themes that way. The last one I had to write was on 'What a Daffodil Thinks of Spring,' and I just couldn't get going."

Bob's soliloquy is as relevant today as it was to the 1940s. It highlights the fact that many students seem to learn effectively in the context of authentic, real-life activities yet have difficulty with the more artificial tasks required in school. A number of researchers have explored the benefits of increasing the learner-centeredness of teaching by actively searching for "funds of knowledge" in students' homes and communities that can act as bridges for helping them learn in school (for example, see Lee, 1995; Moll and Gonzalez, 2004; Moses and Cobb, 2001). Examples include helping students see how the carpentry skills of their parents relate to geometry; how activities like riding the subway can provide a context for understanding algebra; how everyday language patterns used outside of school often represent highly sophisticated forms of language use that may be taught in literature classes as an academic subject yet are not linked to students' out-of-school activities.

Bob's story illustrates the importance of learning more about people's histories as individuals. It is motivating for students to know that teachers care about them, but a teacher's knowledge of her students can affect aspects of learning even beyond motivation. The more we know about someone, the more we are able to connect to their specific interests and needs and explain things in ways that make sense to them. (See "How Personal Knowledge Affects Communication.")

How Personal Knowledge Affects Communication

Imagine playing a game where you hear target concepts and try to get someone you do not know to say them by providing clues but not giving direct answers. For example, in one study a participant received the target "red corvette" and said, "A sports car made by Chevrolet that's the color of fire." Given the target "videodisc" she said "An interactive medium for video that came out before CD-ROMs and was much bigger in size." For the target "brine shrimp" she said, "I'll pass on that one. It's too hard."

Consider the same contestant when told that she was communicating with a person with whom she had worked for over a decade and knew very well. For "red corvette" she said, "What Carolyn drives—be sure to name the color." For "videodisc" she said, "What our Jasper program was published on when it first came out" (Jasper was an interactive videodisc program). For "brine shrimp" she said, "The little orange things that are swimming around in the Ecosystem in my office." Knowing the person to whom she was talking provided a number of shortcuts to communication that otherwise could not have been taken.

Creating Bridges Between Prior Experience and New Knowledge. Even if teachers do not know a great deal about each student, they can encourage students to think about personal experiences that they have had that are relevant to a topic being explored. For example, Banks (2000) discusses a technique that he uses in his multicultural education class to help prospective teachers better understand how minorities often feel marginalized by society. He doesn't begin simply by giving a lecture on minorities and marginalization, as it can be difficult for nonminority students to develop a deep and empathetic understanding of the issues simply by hearing a lecture. Instead, Banks begins work on this topic by asking his students to write a short summary of a time when they felt marginalized by another group. He notes that almost everyone, whether from a minority culture or the majority culture, has had such an experience at some time in their lives. After writing their short essays, students are now in a better position to understand the significance of issues that Banks discusses in class.

Another example of being learner-centered is illustrated in "Connecting Content to Learners." This account of two teachers who approached teaching in very different ways provides an illustration of how "pedagogical content knowledge" (see Chapter Six)—that is, the ability to make subject matter knowledge accessible to students—is developed by combining an understanding of content with an understanding of learners' needs and perspectives. Taking learner's perspectives into account in this way integrates the knowledge-centered and learner-centered aspects of teaching.

Connecting Content to Learners

Two new English teachers, Jake and Steven, who graduate from elite private universities with similar subject matter backgrounds, set out to teach *Hamlet* in high school (Grossman, 1990). Jake went directly into teaching after graduating from college with a major in English. Steven spent an additional year after college in a master's degree program preparing to teach English.

In his teaching, Jake spent seven weeks leading his students through a word-by-word *explication du texte*, focusing on notions of "linguistic reflexivity," and issues of modernism. His assignments included in-depth analyses of soliloquies, memorization of long passages, and a final paper on the importance of language in *Hamlet*. Jake's model for this instruction was his own undergraduate coursework; there was little transformation of his knowledge, except to parcel it out in chunks that fit into the 50-minute containers of the school day. Jake's image for how students would respond was his own response as a student who loved Shakespeare and delighted in close textual analysis. Consequently, when students responded in less than enthusiastic ways, Jake was ill-equipped to understand their confusion: "The biggest problem I have with teaching by far is trying to get into the mind-set of a ninth grader . . . "

Thinking about how to connect the themes of *Hamlet* to his students' experiences, Steven began his unit without ever mentioning the name of the play. To help his students grasp the initial outline of the themes and issues of the play, he asked them to imagine that their parents had recently divorced and that their mother had taken up with a new man. This new man had replaced their father at work, and "there's some talk that he had something to do with the ousting of your dad" (Grossman, 1990, p. 24). Steven then asked students to think about the circumstances that might drive them so mad that they would contemplate murdering another human being. Only then, after students had contemplated these issues and done some writing on them did Steven introduce the play they would be reading. As described in Grossman (1990), the results of these different strategies were dramatically different in terms of students' engagement with and eventual learning of the text.

Learner-Centeredness, Metacognition, and Basic Cognitive Processes

Being learner-centered also involves an awareness of some basic cognitive processes that impact learning for all people. A branch of psychology called "information processing" (see, for example, Atkinson and Schiffrin, 1968) has explored a number of these processes. Work in this tradition becomes especially beneficial for education when it is used to help people learn about the cognitive processes that underlie their own abilities to learn and solve problems. This knowledge is often called "metacognition" (knowledge about one's own cognitive processes; see Brown, 1997b; Flavell, 1976). Some teachers have been known to introduce the idea of metacognition to students by saying, "You are the owners and operators of your own brain. But it came without an instruction book. It pays to learn how it works."

Attention and Fluency. Learning about attention is one important part of becoming a metacognitive learner. First, we can selectively attend to information. When reading the preceding sentence you probably did not attend to how often the letter "e" occurred, but you could do that if you wanted to. Second, our attention is limited; when we attend to one set of features (for example, whether the words in the earlier sentence contain the letter "e"), we miss other features (for example, the meaning of the sentences; see Craik and Lockhart, 1972; Hyde and Jenkins, 1969). There are important constraints on how much we can attend to at any particular point in time.

The amount of attention that we must devote to a task depends on how experienced and efficient we are at doing it. For example, unlike a novice driver, an expert can drive a car and carry on a conversation at the same time. Over time, driving has become "fluent" or "automatized" (highly efficient), which then frees up attention to do other things like converse with fellow passengers. But even for the experienced driver, intense weather or driving conditions can produce demands on attention that shut down the ability to also converse or, in some cases, even listen to the radio.

In contrast to experienced drivers, a novice has to pay a great deal of attention to each component of driving—turning the wheel the right amount, hitting the brake pedal rather than the accelerator, using the turn signals and shifting if the car has a stick shift. During early phases of learning, it is almost impossible for the novice to drive effectively and carry on a conversation. As driving becomes more automatic or fluent, the ability to multitask increases.

A number of studies have explored the concept of attentional demand and its relationship to fluency. When learning to read, for example, the effortful allocation of attention to pronouncing words can make it difficult to also attend to the meaning of what one is reading. When learning a new video game, students will often need to allocate all their attention to the game. Only when they become fluent at playing can they then begin to converse about everyday events or about what they are doing as they play.

The attentional demands that accompany attempts to learn anything new mean that all learners must go through a period of "klutziness" as they attempt to acquire new skills and knowledge. Whether people persist or bail out during these "klutz" phases depends in part on their assumptions about their own abilities. Some people may decide "I'm not good at this" and give up trying before they have a chance to learn effectively (see, for example, Dweck 1986). Wertime (1979) notes that an important part of being learner-centered is to help students learn to persist in the face of difficulty by increasing their "courage spans."

Short-Term Memory. Information processing theorists have also explored differences between short-term and long-term memory. If you look up a phone number and walk across the room to dial it (for example, 614-277-4883), you may rehearse it as you walk. This is one way to keep information active in short-term memory. However, after you dial the information you may not remember it later because it was not transferred to long-term memory. To achieve the latter you may need to rehearse for a longer period or use special strategies (for example, "the first part, 614, fits my brother's birthday (6/14) . . . " and so on).

Researchers have asked how knowledge about the need to use various strategies develops with experience. Consider the simple act of rehearsing information like a new phone number so that you won't forget it as you walk across the room to dial it. Are we born with knowledge of the need to rehearse or does it develop over time? (See "A Study of 'Metamemory.'")

A Study of "Metamemory"

Imagine that you and a number of first graders participate in an experiment where you are shown pictures of seven common objects such as car, table, book. An experimenter points to four of the pictures (for example, book, dog, tree, table). Your task is to wait fifteen seconds (you cannot see the pictures during this time) and then point to the pictures in the same order. After you report your answer, the experimenter points to another order of the set of pictures and you try to remember this order. This procedure is repeated for several trials. To be correct on each trial, what strategy would you use?

The answer to this question seems obvious. Most adults use the strategy of mentally rehearsing the names of the pictures to themselves during the fifteen-second segment between presentation and test. Thus they may say to themselves, "book, dog, tree, table; book, dog, tree, table," perhaps while also imagining these objects.

A classic study by Keeney, Cannizzo, and Flavell (1967) shows that younger children do not always rehearse even though they seem very motivated to remember. The researchers provided a task like the one described earlier to first graders. One of the experimenters was trained in lipreading. He watched for any subtle lip movements that might accompany the children's attempts to rehearse the information. Only some of the children showed signs of rehearsal, and rehearsal helped their performance. Those who rehearsed performed better than those who did not seem to rehearse.

Keeney and his colleagues also asked whether it was possible to teach strategies to the first graders who did not rehearse spontaneously. They found that it was possible to teach rehearsal and that, on trials when they were explicitly reminded to rehearse, the children's memory performance improved.

The experiment was extended to include additional trials, but without the explicit reminders to rehearse on each trial. A large number of the children stopped using rehearsal strategies on these extra trials despite the fact that they seemed motivated to remember the information. They apparently did not understand that rehearsal was necessary in order to do well in the memory task.

Storage Versus Retrieval. Another aspect of metacognition involves realizing the difference between storing information in long-term memory and being able to retrieve it. Having someone's name "on the tip of your tongue" is a good example of these differences—it's somewhere "in memory" but you can't quite get to it and hence are not able to generate the name (retrieve it). However, you can often recognize the name if someone gives you several choices and asks you to pick.

Different kinds of tests place different demands on retrieval. Multiple-choice exams place less emphasis on retrieval than essay exams. To perform on an essay test, people need to create retrieval schemes that can help them perform effectively. If you are writing about the history of different countries, for example, it can be helpful to think of a retrieval scheme such as "STEPS plus G," which can help you remember to write about science at the time, technology, economics, political systems, social and religious practices, and geography. Without some kind of retrieval scheme, people who have stored a great deal of relevant information may fail to retrieve all of it at the time of test.

Comprehension. Another important aspect of metacognition involves monitoring to see if we are comprehending something appropriately. Without active monitoring we often think we understand when we don't (recall the fish's interpretation of cows, birds, and so on). The ability to monitor our own understanding is not simply a general skill, it requires knowledge that helps people notice discrepancies between what they currently understand and what they need to know. If you are a detective, for example, you can understand a suspect's statement that "I visited my mother yesterday and she and her friends will testify that I was there." But you will also realize that you need more information—such as the exact time of day when the witness visited compared to the time of day of the crime.

Experts in various areas (for example, crime detectives, engineers, teachers, and so forth) develop specialized organizations of knowledge (often called scripts and schemas) that help them comprehend, remember, and monitor whether all the information necessary for particular schemas has been provided (see, for example, Black and Bower, 1979; Pichert and Anderson, 1977; Schank and Abelson, 1975). For example, the schemas available to crime detectives help them notice the significance of particular kinds of information and guide their search for additional information. Detectives know about phone records and other types of information that can be used to check on the accuracy of statements people make.

Often students who are new to a topic do not have enough experience in that area to have developed scripts and schemas that help provide internal standards for monitoring. It is therefore important to "make their thinking visible" so that teachers and peers can help this monitoring. We saw this earlier in the *Fish is Fish* example. Maybe the fish could have been a little more metacognitive and done more to check its interpretations. But without knowledge of the potential variation of creatures in the world, it can be difficult for the fish to know what else it needed to know or ask.

In other cases, people may have knowledge of standards that enable them to monitor their performances but do not do so spontaneously unless explicitly prompted. Studies show that "metacognitive training" can have powerful effects on helping students increase their abilities to comprehend by monitoring the current state of what they do and do not know (see, for example, Palincsar and Brown, 1984; White and Fredrickson, 1998).

Motivation. Helping students learn to identify what motivates them is also an important part of being learner-centered. Researchers have explored differences between extrinsic motivators (grades, money, candy, and so forth) and intrinsic motivators (wanting to learn something because it is relevant to what truly interests you). Both kinds of motivation can be combined; for example, we can be intrinsically interested in learning about some topics *and* interested in receiving extrinsic rewards as well (for example, praise for doing well, a consultant's fee). However, some research suggests that too much of an emphasis on extrinsic rewards can undermine intrinsic motivation because people get too used to the external rewards and stop working when they are removed (see, for example, Deci, 1978). (See also Chapter Nine.)

There appear to be important differences between factors that are initially motivating (the assumption that learning to skateboard seems interesting), and factors that *sustain* our motivation in the face of difficulty ("hmm, this skateboarding is harder to learn than it looked"). The social motivation support of peers, parents, and others is an especially important feature that helps people persist in the face of difficulties. It is also important to be provided with challenges that are just the right level of difficulty—not so easy that they are boring and not so difficult that they are frustrating. Creating the right kinds of "just manageable difficulties" for each student in a classroom constitutes one of the major challenges and requires expert juggling acts. (Explorations of the literature on motivation can be found in Deci and Ryan, 1985; Dweck, 1986; Stipek, 2002.)

Transfer. Learning about ourselves as learners also involves thinking about issues of transfer—of learning in ways that allow us to solve novel problems that we may encounter later. The mere memorization of information is usually not sufficient to support transfer; instead, it helps also to understand what we are learning. In Chapter One, we discussed differences between memorizing facts about veins and arteries versus understanding why each had particular properties (for example, why arteries needed to be more elastic than veins). Learning with understanding typically enhances the experience (see, for example, National Research Council, 2000). A classic study on learning, understanding, and transfer appears in "Learning for Transfer."

Learning for Transfer

In one of the earliest studies comparing the effects of learning a procedure versus learning with understanding, two groups of children practiced throwing darts at a target under water (described in Judd, 1908; see Hendrickson and Schroeder, 1941, for a replication). One group received an explanation of the refraction of light, which causes the apparent location of the target to be deceptive. The other group only practiced dart throwing, without the explanation. Both groups did equally well on the practice task, which involved a target twelve inches under water. But the group that had been instructed about the abstract principle did much better when they had to transfer to a situation in which the target was under only four inches of water. Because they understood what they were doing, the group that had received instruction about the refraction of light could adjust their behavior to the new task.

An important goal for transfer is cognitive flexibility (see, for example, Spiro and others, 1991). Experts possess cognitive flexibility when they can evaluate problems and other types of cases in their fields of expertise from many conceptual points of view, seeing multiple possible interpretations and perspectives. Wiggins and McTighe (1998) argue that understanding complex issues involves being able to explain them in more than one way. Spiro and others (1991) argue that the inability to construct multiple interpretations in analyzing real-world cases can result from instruction that oversimplifies complicated subject matter. Additional discussions of transfer occur later on.

Assumptions About "Intelligence." A major set of assumptions that can have important effects on learning and motivation are the assumptions that people make about intelligence—both their own and others'. Many Americans and Europeans have grown up with the belief that "intelligence" is something that is inherited and places limits on people's abilities to learn. In the first half of the twentieth century, many schools also accepted this belief and hence took it as a given that many students would fail.

More recent evidence suggests that is not productive to attempt to measure people's abilities on a single dimension like IQ (intelligence quotient). A number of researchers argue that people's capacity to be productive citizens and workers is multidimensional rather than unidimensional (see, for example, Gardner, 1983; Sternberg, 1985a). It has also been argued that human capacity is open-ended; hence people can "grow" their intellectual capacity (see, for example, Perkins, 1995; Resnick and Nelson-LeGall, 1998). As discussed in the following section, there is evidence from neuroscientists that learning not only depends on the structure of brain but also actually influences brain development (see, for example, National Research Council, 2000). An important implication of these positions is that no one really knows the upper limits of human intelligence.

Overall, there is growing agreement that even though there may be individual differences in biological aptitudes for learning certain kinds of things (music, social skills, and so on), most of functional intelligence is learnable and hence also teachable. People's *beliefs* about intelligence are a major factor in affecting what they can learn. A number of researchers have shown that many children in the United States (but not necessarily in many Asian countries) have come to believe that educational accomplishments are due to "aptitude" rather than "effort" (Resnick and Nelson-LeGall, 1998). Students who question their own academic aptitudes (often because of social stereotypes like "girls can't do math") are more likely give up when they experience difficulties (Mueller and Dweck, 1998). Similarly, even very able students who have come to think that achievement is a function of ability, rather than effort, often give up when they encounter a difficult task, believing that if they have trouble, it is because they are unable. As noted earlier, this is very serious because novices typically experience a "klutziness" phase when they are learning something new, and beliefs about intelligence affects people's interpretations of why this klutziness is happening to them.

Assumptions About Brain Development. Assumptions about intelligence are often linked to assumptions about "brain efficiency." It is a common

misconception that individuals' intelligence and brain development are entirely predetermined by biology. In reality, education and experience actually help develop the brain. Physical and mental activities of various kinds help people develop their capacity to learn, and what teachers do can affect brain development by engaging students in activities that help them develop their capacities. This can range from the kind of neurological programming that occurs when musicians practice certain patterns of physical movement tied to symbol systems (reading music) and when readers practice letter-sound correspondences and learn comprehension strategies. Learning abilities can be developed by access to an environment that stimulates and uses the brain. (See "How Environments Affect Brain Development.")

How Environments Affect Brain Development

A pioneering study on the effect of the environment on brain development was conducted by William Greenough and his colleagues (1979). They studied rats placed in various environments and the resulting effects on synapse formation in the rats' brains. They compared the brains of rats raised in "complex environments," containing toys and obstacles, with those housed individually or in small cages without toys. They found that rats raised in complex environments performed better on learning tasks like learning to run mazes, and they had 20 to 25 percent more synapses per neuron in the visual cortex. This work suggests that brain development is "experience dependent," allowing animals to acquire knowledge that is specific to their own environments. These experiments suggest that "rich environments" include those that provide numerous opportunities for social interaction, direct physical contact with the environment, and a changing set of objects for play and exploration (Rosenzweig and Bennett, 1978b, cited in National Research Council, 2000, p. 119). Similarly, rich classroom environments provide interactions with others in the classroom and community, hands-on experiences with the physical world, and frequent, informative feedback on what students are doing and thinking.

New advances in technology are allowing scientists to go beyond the study of animals and explore how *humans* process information. In emerging brain research, imaging technologies are helping scientists localize areas of brain activity that underlie the cognitive components of a task; with imaging, areas of the brain are shown to "light up" under varying conditions. For example, the physical activity of the brain during reading differs for dyslexics and non-dyslexics. Some researchers have relied on these images to improve understanding of how to teach dyslexic students (Berninger and Richards, 2002).

Although research on the human brain is progressing rapidly, direct connections between brain science and specific teaching practices are not clear at this point. Bruer (1997) argues that, for now, educators should rely primarily on research on cognition, development, and teaching practices and keep an eye out for new developments in the neurosciences that have implications for these fields.

Community-Centeredness

The preceding discussion explored a number of issues relevant to being knowledge-centered and learner-centered. The community-centered aspect of the HPL framework is related to being knowledge- and learner-centered, but it focuses special attention on the social nature of learning, including the norms and modes of operation of any community we are joining. For example, some classrooms represent communities where it is safe to ask questions and say, "I don't understand this, can you explain it in a different way?" Others follow the norms of "Don't get caught not knowing something." A number of studies suggest that, to be successful, learning communities should provide people with a feeling that members matter to each other and to the group, and a shared belief that members' needs will be met through their commitment to work together (Alexopoulou and Driver, 1996; Bateman, Bransford, Goldman, and Newbrough, 2000). Many schools are very impersonal places, and this can affect the degree to which people feel part of, or alienated from, important communities of professionals and peers.

Community-Centeredness, Productivity, and Distributed Expertise

It is easy to do a quick *Fish is Fish* interpretation of the community-centered part of the HPL framework and assume that it is mainly an argument for creating classroom environments where students are helped to "feel good" about themselves but are not necessarily held to high standards. This is where the balance in the HPL framework plays a role—all four components affect the quality of the learning environments. Most importantly for present purposes, the idea of functioning as a community or team goes way beyond simply making everyone feel good because they are part of a group.

If you have ever been involved in a disaster such as a flood, hurricane, or tornado, you know what it is like for people to pull together in ways that are highly productive. Team activities often provide similar bonds of shared fate. Especially important is the fact that the ideal of being community-centered does not mean that everyone simply agrees with everyone else about everything. True learning communities learn from one another and know how to "argue with grace." As people share their understandings and reasoning with one another, they teach each other in a variety of ways. Not only are ideas shared, but modes of argumentation, reasoning, and problem solving are also modeled and shared. This helps others develop their thinking abilities as well as their store of knowledge. In addition, the various skills and interests provided by members of a learning community offer access to distributed expertise that can be skillfully used to support the learning of all participants in the community. A major part of classroom management involves the development of a respectful argument-based learning community in which students benefit from each other's knowledge and views (see Chapter Nine).

Concerns that many schools are impersonal and need to be smaller to be more learner- and community-centered can also be misinterpreted as simply being an argument for helping students feel good about themselves. This is very important, of course, but more is involved as well. The communication game discussed in How Personal Knowledge Affects Communication (for example, helping someone to guess "red corvette" or "brine shrimp") and the previous story about Bob (the "problem student" who nevertheless learned well outside of school) demonstrate the importance of searching for "funds of knowledge" in students' lives that can be built upon to enhance their motivation and learning. The more we know about people the better we can communicate with them and hence help them (and ourselves) learn. And the more they know about one another, the better they can communicate as a community.

Vygotsky and Community-Centeredness

The importance of creating and sustaining learning communities can be traced to Vygotsky's theory in which culture and human interaction play a central role in developmental processes. Earlier we discussed Piaget, who tended to focus on individual learners as they explored their environments. People do explore individually, of course. Nevertheless, Vygotsky (1978) emphasized that learning is highly social and mediated by one's culture. In his book *Mind in Society*, he argued that even the development of the human brain is influenced by activities of the cultures within which people participate. As noted earlier, these assumptions about the brain—made many years ago—are being confirmed by modern neuroscientists. The brain is not fixed at birth; instead, it develops as a function of the social activities in which people are engaged (see, for example, National Research Council, 2000).

Vygotsky also focused on the intersection between individuals and society through his concept of the zone of proximal development (ZPD). He defined the ZPD level 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 (Vygotsky, 1978, p. 86). What children can do with the assistance of others is even more indicative of their mental development than what they can do alone (Vygotsky, 1978, p. 85).

The zone of proximal development redefines everyday assumptions about people's "readiness to learn" by emphasizing upper levels of competence. These upper boundaries constantly change with the learner's increasing independent competence. What a child can perform today with assistance she will be able to perform tomorrow independently, thus preparing her for entry into a new and more demanding collaboration. These functions could be called the "buds" rather than the fruits of development. The actual developmental level characterizes mental development prospectively (Vygotsky, 1978, pp. 86–87). The ZPD is relevant to both learner- and community-centeredness. For the latter, teachers must balance the fact that, in most classrooms, multiple learning trajectories, or zones of proximal development, must be taken into account (see Brown and Campione, 1994). An example is provided in "Becoming Aware of Different Learning Trajectories."

Becoming Aware of Different Learning Trajectories

A research group wrote about an important lesson they learned that is relevant to one aspect of Vygotsky's theory of zone of proximal development (Cognition and Technology Group at Vanderbilt, 1997). The researchers were observing a teacher who had a reputation for being outstanding, but what they observed alarmed them. The teacher was working with middle school students on mathematical problems that were motivating but difficult to solve. Students typically worked in groups, but often they presented on their own. The problems could be solved in a variety of ways; a major goal of the presentations was to have the students explain why they had made particular choices in strategies. This is very different from simply repeating the computations that were used to get some answer at the end.

What shocked the research group was the fact that this allegedly outstanding teacher praised what was clearly a less than stellar performance by a student. The student's oral presentation of his mathematical solution to the complex problem was OK, but he provided no explanation of why he had chosen particular solution strategies. Despite this fact, the teacher praised the student and the class clapped. The research group became alarmed that the teacher's criteria for "good work" was much too low and that this would harm the students in the long run. They thought the teacher knew that the work in mathematics was supposed to focus on explanations, but evidently he did not.

The event occurred on a Friday and several members of the research group talked over the weekend about how to help the teacher. They didn't want to hurt his feelings, but the students' learning was at stake. Eventually the researchers decided to ask the teacher what he had thought about Friday's lesson, so they visited him on Monday and asked what he thought about Friday's class. His answer was: "It was one of the highlights of my teaching career." He explained that this was the first time in the entire year (it was early December) that the young man who had presented on Friday had gotten the courage to speak up in class. To be sure his performance wasn't perfect, and the teacher would have preferred that he offer explanations of his solution rather than simply recite his calculations. But overall the performance was a huge victory. The boy had told his parents about it and they had called the teacher to thank him. The class also realized that this was a big event, which is why they clapped.

The research group learned a valuable lesson. They didn't know enough about the young man to realize that his performance had represented true progress. They listened as the teacher explained how he carefully crafted expectations for different students depending on where they started—he didn't teach as if every student was on a conveyor belt where every student was expected to be able to the same thing at the same time. The teacher took seriously the idea that different students required different kinds of support (scaffolds) to make progress. At the same time, the teacher took seriously the need for all students to reach high standards. He was sure that, by the end of the year, the young man who had spoken for the first time on Friday would be able to explain his answers as well as simply describe them. He wanted high standards for all his students, and he realized that the kind of community culture that he developed in the classroom was an important part of helping him reach his goal.

A number of chapters in this book explore issues that are relevant to the community-centered aspects of learning environments. One is Chapter Nine, Classroom Management, which helps demonstrate how building such a community can be used in the service of stronger achievement.

At a broader level, being community-centered also means reaching beyond the walls of the schools to connect with students' out-of-school experiences, including experiences in their homes. In *How People Learn* (National Research Council, 2000), an analysis of time spent in school in a major school district during a calendar year indicated that even with perfect attendance, students spent only 14 percent of their time in school. A great deal of learning occurs outside of school, but often teachers do not know how to connect these kinds of experiences to school learning. Earlier we discussed the story of Bob (the so-called "problem" student) and related it to the idea of searching for "funds of knowledge" that exist in communities and can be built upon to help students succeed. Helping students build strong social networks within a classroom, within a school, and between classrooms and outside resources produces a number of advantages that are discussed in more detail in Chapters Three and Nine.

Assessment-Centeredness

We've discussed knowledge-, learner-, and community-centeredness; now we turn to assessment-centeredness. It is easy to assume that assessment simply involves giving tests to students and grading them. Theories of learning suggest roles for assessment that involve much more than simply making up tests and giving grades.

First, teachers need to ask what they are assessing. This requires aligning their assessment criteria with the goals for their students (part of being knowledge-centered) and the "readiness" of students in their classroom (learner- and community-centered). Assessing memorization (for example, of properties of veins and arteries) is different from assessing whether students understand why veins and arteries have various properties. (See Chapter One for the veins and arteries example.) Similarly, assessing whether students can answer questions about life cycles (of frogs, for example) is different from assessing whether they will spontaneously retrieve this information when attempting to solve problems. (Note the example in Knowledge Organization and Problem Solving about students' responses to the ultraviolet experiment that used adult frogs.) We also saw earlier that knowledge about students' zones of proximal development can help teachers decide to use different criteria for assessing students' progress. For example, in Becoming Aware of Different Learning Trajectories, we discussed the young man who presented his problem-solving solution in a way that did not fit ultimate standards for excellence, but the teacher applauded because he knew that this was the first time in the entire school year that the student had dared speak in front of the class.

At the most general level, issues of what to assess relate to issues of what students need to know and be able to do to have fulfilling lives once they graduate. Because of rapid changes in society, this is an issue that constantly needs to be reconsidered. Debates about standardized tests include concerns that they may "tip" teaching in a direction that is counterproductive for students because some teachers spend most of their time teaching to the tests, yet the tests do not assess the range of skills, knowledge, and attitudes needed for successful and productive lives in the twenty-first century. Chapter Eight, on assessment, explores this issue in more detail.

Different Kinds and Purposes of Assessment

An especially important aspect of the assessment-centered lens in the HPL framework is its emphasis on different kinds of assessments for different purposes. When most people think about assessments they think about *summative assessments.* These include standardized tests at the end of the year, final exams at the end of a course, and unit exams at the end of a unit. Summative assessments come in all forms: multiple-choice tests, essays, presentations by students, and so forth. These assessments are very important. Often they reveal important information that teachers wish they had seen earlier. The vignette at the beginning of this chapter about Paul Nelson, the astronomy teacher who discovered that his students still misunderstood important concepts about the earth and its seasons, provides an example of this point. Paul thought that everyone understood the lessons about the solar system and earth's systems, but the essay exams provided a different picture. If he had known earlier what the students were thinking, he could have returned to the topic and explored it from a different perspective. Now it was too late. The students had written their final essays and were finished with the class. Their *Fish is Fish* interpretations would follow them out the door. Paul's anguish could have been reduced if he had used what are called formative assessments. These are used for the purpose of improving teaching and learning. They involve making students' thinking visible *as they progress through the course,* giving them feedback about their thinking, and providing opportunities to revise.

The importance of frequent feedback was emphasized by one of the earliest research traditions in America to study learning—the Behaviorist tradition.

People such as J.B. Watson, Ivan Pavlov, and B.F. Skinner were major contributors to this line of thinking. They searched for universal laws of learning that could apply not only across individuals but across species (rats, pigeons, monkeys, humans). Their emphasis was on the role of positive and negative feedback in helping organisms learn to perform complex skills.

An early contributor to the Behaviorist movement was Thorndike, who became known as "The father of educational psychology." His famous "law of effect" stated that rewards strengthened connections between particular stimulus conditions and particular outcomes. When responses were rewarded, they tended to be repeated when those stimulus conditions appeared again.

Rewards and punishments carry information (feedback) about the "correctness" of one's actions (responses), and Thorndike emphasized the importance of feedback for learning. In a clever demonstration study (1931/1968), Thorndike decided to learn to draw lines that were exactly 4 inches long with his eyes blindfolded. He practiced for 3,000 trials but never received any feedback about how close each attempt was. Without feedback, he made no progress. On the first day of blindfolded practice, his lines varied from 4.5 to 6.2 inches. On the last day, they varied from 4.1 to 5.7 inches—still quite a ways from a perfect 4-inch mark.

Thorndike concluded that practice does not make perfect unless it provides the opportunity for feedback. Once he removed his blindfold, he improved very rapidly because he received feedback that allowed him to compare his behavior to a standard (a 4-inch line). Today, research in cognitive science has shown that formative assessment and the feedback it provides is extremely important for enhancing learning (see, for example, Black and William, 1998). The chapter on assessment (Chapter Eight) provides much more information about the importance of formative assessment for helping all students succeed.

Assessment and Theories of Transfer

It is also important for teachers to understand ways in which assessment practices relate to theories of transfer. Consider summative assessments, for example. We all want to make sure that these provide an indication of students' ability to do something other than simply "take tests." Ideally, our assessments are predictive of students' performance in everyday settings once they leave the classroom.

One way to look at this issue is to view tests as attempts to predict students' abilities to *transfer* from classroom settings to everyday settings. Different ways of thinking about transfer have important implications for thinking about assessment. Central to traditional approaches to transfer is a "direct application" theory and a dominant methodology that Bransford and Schwartz (1999) call "sequestered problem solving" (SPS). Just as juries are often sequestered to protect them from possible exposure to "contaminating" information, subjects in experiments are sequestered during tests of transfer. There are no opportunities for them to demonstrate their abilities to learn to solve new problems by seeking help from other resources such as texts or colleagues or by trying things out, receiving feedback, and getting opportunities to revise. Accompanying the SPS paradigm is a theory that characterizes transfer as the ability to directly apply one's previous learning to a new setting or problem. We call this the direct application (DA) theory of transfer. Some argue that the "sequestered problem-solving" methodology and the accompanying direct application theory of transfer are responsible for much of the pessimism about evidence for transfer (Bransford and Schwartz, 1999).

An alternative view that acknowledges the validity of these perspectives also broadens the conception of transfer by including an emphasis on people's "preparation for future learning" (PFL). Here, the focus shifts to assessments of people's abilities to learn in knowledge-rich environments. When organizations hire new employees they don't expect them to have learned everything they need for successful adaptation. They want people who can learn, and they expect them to make use of resources (for example, texts, computer programs, and colleagues) to facilitate this learning. The better prepared they are for future learning, the greater the transfer (in terms of speed and quality of new learning). Examples of ways to "prepare students for future learning" are explored in Schwartz and Bransford (1998), Bransford and Schwartz (1999), and Spiro, Vispoel, Schmitz, Samarapungavan, and Boeger (1987).

It is important to emphasize that the preparation for learning perspective on transfer does not assume the existence of a set of general learning skills that are content free. The expertise literature (see, for example, Bransford and others, 1999) shows clearly how strategies and knowledge are highly interdependent. Broudy (1977) provides an example: "The concept of bactërial infection as learned in biology can operate even if only a skeletal notion of the theory and the facts supporting it can be recalled. Yet, we are told of cultures in which such a concept would not be part of the interpretive schemata" (p. 12).

The absence of an idea of bacterial infection should have a strong effect on the nature of the hypotheses that people entertain to explain various illnesses, and hence would affect their abilities to learn more about causes of illness through further research and study, and the strategies one uses to solve new problems. The acquisition of well-differentiated knowledge is crucial for future learning (see, for example, Bransford and others, 1999; Schwartz and Bransford, 1998; Spiro and others, 1987). The more that this knowledge is acquired with understanding, the higher the probability that appropriate transfer will occur.

The sole use of static assessments may mask the learning gains of many students, as well as mask the learning advantages that various kinds of educational experiences provide (Bransford and Schwartz, 1999). Linking work on summative assessment to theories of transfer may help us overcome the limitations of many existing tests. An example of the difference between "sequestered problem solving" versus "preparation for learning" assessments of learning and transfer is provided in the following section.

"Sequestered Problem Solving" Versus "Preparation for Learning" Assessments of Transfer

Groups of fifth graders and college students were given the problem of developing a statewide recovery plan to protect bald eagles (Burgess, as discussed in Bransford and Schwartz, 1999). None of the students had studied eagle recovery plans before. The study was meant to see if the college students' general education experience would transfer to solving this problem. Both the college students and the fifth graders gave very inadequate solutions to this problem. Using a direct method of measuring transfer, it is apparent that the college students' general educational experiences did not transfer to solving this kind of problem. However, by measuring transfer as preparation for future learning, the college students' educational experiences did transfer. The researchers asked both groups to generate questions regarding important issues that they would need to research to develop an effective recovery plan. The differences between the college students and the fifth graders were convincing. The fifth graders' questions focused more on individual eagles (for example, What do they like to eat? What size are they? What kinds of trees do they live in?). College students' investigative questions focused more on the relationship between eagles and their habitat (for example, What kinds of ecosystems support eagles? What different types of experts are needed to carry out the recovery plans? Do other animals need to be recovered in order to recover eagles?). So, by this second measure of transfer, it seems college students used prior knowledge from other zoology or biology classes to help shape their future learning about a to-be-investigated topic. Several additional studies show that PFL measures of transfer can reveal the advantages of many kinds of educational experiences that remain relatively invisible when assessed from an SPS point of view (see, for example, Biswas and others, 2001; Schwartz and Moore, 1998; Schwartz, Lin, Brophy, and Bransford, 1999).

THE HPL FRAMEWORK IN ACTION

We have discussed all four components of the HPL framework, but we noted earlier that learning occurs most effectively when all four components are balanced. Underemphasizing one or more of the components can make it harder for all students to succeed. For example, teachers can be overly learner-centered and community-centered, yet fail to emphasize the acquisition of important concepts and skills (knowledge-centered) that students need for successful lives. And if teachers are not assessment-centered (especially in their use of formative assessments), they may fail to realize that students are not making adequate progress until the year is over and it is too late for them to help.

The HPL framework becomes a powerful conceptual tool for teachers when they use it to analyze the quality of various learning environments. With this goal in mind, imagine observing a middle school English teacher who is teaching a unit on stories and poetry that explore subjects of nature and ecology. She has instructed her students to read various nature writings and to select one of them to recite aloud to the class from memory. One of the students, Henry, chooses the following excerpt from Leopold's *Sand County Almanac*: "I now suspect that just as a deer herd lives in mortal fear of its wolves, so does a mountain live in mortal fear of its deer. And perhaps with better cause, for while a buck pulled down by wolves can be replaced in two or three years, a range pulled down by too many deer may fail of replacement in as many decades. So also with cows. The cowman who cleans his range of wolves does not realize that he is taking over the wolf's job of trimming the herd to fit the range. He is not thinking like a mountain. Hence we have dustbowls, and rivers washing the future into the sea" (Leopold, 1949/1990). Assume that Henry recites the piece flawlessly and the teacher and class applaud. How might the HPL framework help us think more deeply about this event?

Knowledge-Centeredness

Adopting this lens draws attention to questions about what should be taught and why. It is possible that this assignment was in a textbook and the teacher taught it simply because it was designed as "the next lesson." Ideally, more thought was involved in deciding that this unit was worth teaching. The teacher probably consulted national, state, and district standards for her discipline and aligned her teaching to these standards. And maybe the teacher even planned collaboratively with a science teacher so that both could focus on issues of ecology from different points of view (scientific evidence coupled with literature and art).

The knowledge-centered lens has implications for other HPL lenses such as assessment. For example, can we say that Henry learned effectively and that, for him at least, the lesson was a success? The answer depends on the teachers' goals for the lesson (which we will assume for this example are consistent with the district, state, and national standards).

The primary goal may have been to help students learn to perform by committing ideas to memory and delivering them in a powerful, emotional manner (rather than in a monotone, for example). This can be a valid and important goal for students, and from this perspective Henry has done very well. The goals might be different, however. For example, the teacher might have wanted all the students to develop a deep understanding of the pieces they are reciting. Based on Henry's performance as outlined so far, it is not clear if he understands what he has memorized.

Assessment-Centeredness

The assessment-centered lens of the HPL framework focuses on ways that different teaching and learning goals impact what teachers do to assess progress. If the goal is a dramatic recitation performance, the teachers will look at criteria

for success that differ from those that signal learning with understanding. And if both of these are important, both need to be represented in the assessment criteria.

Assume that the teacher wants good oral performance *plus* a deep understanding of what the students have read. In Henry's case, the teacher might say: "Nice job Henry. Now tell the class what you think it means." Imagine Henry staring at the teacher for a few seconds and then saying, "Wolves are important. That's about all I can think of." Given the teacher's goal of having students understand as well as perform, Henry's answer is less than ideal. If the teacher treats this event as a summative assessment, she may simply assign Henry a grade (perhaps a "C" or "D") and go on to the next student. Ideally, this event is a formative assessment and the teacher's goal is to help Henry improve his abilities to comprehend the story. To do this the teacher must consider both the learner-centered and community-centered lenses of the HPL framework.

Learner-Centeredness

This lens from the HPL framework focuses attention on individual students and their special strengths, interests, and needs. The teacher's knowledge of Henry is very important for helping define his zone of proximal development, which will in turn help the teacher chose new learning goals and instructional procedures that will optimize Henry's learning.

It is possible that Henry is similar to the boy discussed in Becoming Aware of Different Learning Trajectories who had never before dared to speak in class. In that case, the teacher knew that the boy's attempt to say anything in front of the class was a huge leap forward. In Henry's case, however, we'll assume that he is used to talking in class and the teacher feels that he has the potential to more deeply understand what he read.

Here is an example of how the teacher might work with Henry:

TEACHER (T): So Henry, what do you think Leopold is saying here?

HENRY (H): I don't know. It doesn't make any sense to me, really.

T: Okay. Well, what do you know about overpopulation? (This represents an attempt to see if Henry already knows something that the teacher can use to help his comprehension.)

H: I know it's bad. (This suggests that Henry knows something about the concept of overpopulation.)

T: Is Leopold talking about overpopulation in this passage? (This represents an attempt to get Henry to use existing knowledge to interpret the present situation—similar to how "parachute" was used earlier to help you understand "The haystack was important because the cloth ripped.")

H: Yeah, he is! He's talking about how too many deer can hurt the side of a mountain and that's what overpopulation can do. (This represents one of those "lightbulb" moments when the application of previously acquired knowledge [overpopulation] provides an insight in a new context.)

T: Then, what do you think Leopold was saying when he said the cowmen were not "thinking like a mountain"? (This represents an attempt by the teacher to help Henry link his new insight to the most metaphorical part of the passage; for example, asking cowboys to think like a mountain.)

H: Well, I never thought of it this way but he's telling us that populations have to be kept in check or our world could end up like the side of that mountain. It's kind of a guideline for us and how we should live.

If teaching were always this easy everyone would rejoice. But even this situation illustrates the complexity of the teacher's juggling act. To be effective, teachers need to make moment-by-moment decisions based on their ongoing assessments of the learners' current levels of understanding and their zones of proximal development (ZPD). To use Piaget's terminology, the teacher's questioning enabled Henry to *assimilate* the meaning of the Leopold passage by incorporating the idea into an already existing schema: "overpopulation." This helped Henry take the next step, which was to expand his existing schema (what Piaget would view as an example of *accommodation* rather than pure assimilation) by viewing overpopulation from the perspective of a mountain rather than only from the perspective of humans. Overall, the more the teacher knows about Henry, the better she can guide instruction so that, eventually, Henry learns how to interpret stories and poems rather than merely recite them from memory.

For this particular lesson, the teacher may or may not adopt additional goals depending on her knowledge of Henry. The goal illustrated earlier was to ask questions that would help Henry understand *a particular story.* A more long-term goal might be to help Henry learn to ask questions that will help him develop the ability to understand a wide variety of stories, not just this one. A successful teaching strategy called "reciprocal teaching" has been shown to help students learn to ask their own questions about stories rather than have to rely on particular questions that their teachers have asked about a story they have read (Palincsar and Brown, 1984). To do so, teachers have to help students develop the abilities to self-assess their own understanding so that they don't always have to rely on someone else to ask the kinds of questions that enable them to decide if they have understood adequately (see, for example, Barron and others, 1998; Brown and Campione, 1994, 1996).

Community-Centeredness

The vignette involving Henry does not provide much explicit information about the community-centered aspects of the classroom and school in which the example took place. However, there are reasons to suspect that classroom norms

have developed where the classmates respect one another's efforts to learn and realize that sometimes learning is a struggle for everyone. The teacher's use of questions to provide Henry with an opportunity for formative assessment and revision suggest that this may have become established as a norm in the classroom—and this is very important for creating a climate of shared learning and respect for learning. Not all classrooms are like this. The famous scene in the movie *Ferris Buehler's Day Off* in which actor Ben Stein lectures in a dead monotone while students struggle comically to stay awake is often appreciated by audiences because they remember many classrooms like it.

Another level of community-centeredness that is not visible in the preceding vignette involves the sense of community among fellow teachers and other adults in the school as a whole. When teachers get along and learn from one another, they provide models that help support student learning, and they are able to share their expertise with one another to improve the overall quality of instruction (see, for example, McLaughlin and Talbert, 2001). Finally, relationships among educators and parents and community members matter greatly. We noted earlier that, for a calendar year, a student with perfect school attendance spends only about 14 percent of his or her time in school. How students spend their time out of school is extremely important for their overall development, and it impacts their success in school. The more teachers can work with others to build upon the goodwill and intellectual resources of the community, the more successful they can be. In this case, it might include bringing in experts from the community who can talk about issues of overpopulation or other issues that are related to the topics being explored in class. Having community members be an audience for student presentation—an audience that asks questions—can be an especially powerful event for students *provided* that teachers have created a sufficient number of prior assessment and revision cycles to allow students to do a good job.

Issues of Motivation

Balancing all four aspects of the HPL framework helps motivation as well as learning. If students know they are learning content and skills that will be important in life, this is motivating. If courses connect with their interests and strengths, and provide interesting challenges to their preconceptions, this is motivating (Dweck, 1989). If students receive frequent feedback that allows them to see their progress in learning and gives them chances to do even better, this is motivating. And if students feel as if they are a valued part of vibrant, "high-standards" learning communities—at the classroom level, school level, and overall community level—this is motivating as well.

Learning Theories and Teacher Preparation

New information about learning, teaching, and transfer is as relevant for preparing new teachers as it is to the education of K–12 students. For example, simply having prospective teachers memorize facts about how to teach is as limiting as simply having students memorize facts about what scientists have discovered. Just as students studying science need to experience the inquiry processes involved in discovering and testing ideas relevant to science, prospective teachers need to experience what it is like to learn in environments that are consistent with learning principles (see, for example, National Research Council, in press). In fact, learning in the ways they are expected to teach may be the most powerful form of teacher education. Most people tend to teach in ways that mirror how they were taught. This means that teacher education programs can benefit from exploring the degree to which their courses and programs are consistent with what is known about how people learn. (See Chapter Ten, where we discuss teacher learning, for a more in-depth treatment of these issues.)

A Vision of Teaching Expertise

A major goal for any professional program is to help students begin to see themselves as developing professionals rather than simply as students whose primary goal is to get good grades (see, for example, the discussion of the six "commonplaces" shared by all professions in Chapter One). The argument here is not that good grades are unimportant. Instead, the argument is that prospective teachers need to be more than simply grade oriented. They need a clear vision of what it means to be a professional and intrinsic motivation to succeed so that they can monitor their progress and make corrections as needed. Without a clear vision of one's ultimate goals and responsibilities as a professional, the metacognitive reflection needed for assessing progress is difficult if not impossible to achieve.

Many education programs are adopting the idea of "adaptive expertise" as the gold standard for being a professional. We discussed the idea of adaptive expertise earlier in this chapter and differentiated it from routine expertise (see, for example, Hatano and Inagaki, 1986). Figure 2.1 (which appears earlier in this chapter) provides two dimensions of expertise (efficiency, innovation) that are very helpful for helping people develop a conception of what it means to be a professional. Adaptive experts are able to balance efficiency and innovation. Helping prospective teachers achieve this balance can be very beneficial: it can guide the "lifelong learning" needed to help all their students achieve.

The efficiency dimension in Figure 2.1 is a "magnet" for novices. Beginners in nearly every area often want step-by-step instruction on how to do things efficiently, and prospective teachers are no exception. Beginners learning to fish or sail want to learn what to do as quickly as possible. Similarly, beginning teachers want to be taught how to manage the classroom; how to organize curriculum and formative and summative assessments that align with local and national standards; how to teach fractions; how to manage group work; how to assign grades fairly; how to balance the hard work required of a teacher with a quality home life; and so forth. In many cases newcomers to an area request a heavy dose of "how to" techniques and are much less interested in theory and explanation about the "whys" and "whens" of the strategies they are taught.

Research on transfer provides important insights into "pure efficiency" training. In Learning for Transfer, for example, Judd's experiment on throwing darts at underwater targets is discussed. Beginners had to learn to throw darts effectively so that they would hit their intended targets. The initial learning rates for doing this were as fast for the "just do it" group as for the group that had been helped to understand the principles of light refraction that create visual displacements of the perceived underwater target. The advantage of learning about visual displacement appeared only when the depth of the underwater target was changed and people needed to adapt their previous learning. To the extent that the world is rapidly changing and that this change will continue to impact educational goals and teaching strategies, prospective teachers need to understand how the natural desire to say, "just tell me what to do" will not serve them optimally for the challenges they will face. As noted earlier, efficiency is extremely important; otherwise, we are overwhelmed by novelty. But efficiency is also insufficient if we want to adapt.

The innovation dimension in Figure 2.1 represents the need to go beyond one's existing efficiency-oriented skills and strategies to adapt to new situations. It is often said that innovation "favors the prepared mind," hence learning with understanding can support innovation and adaptation (for example, see the previous discussion of Judd). We noted earlier that innovation often involves "letting go" of cherished ideas and assumptions. Teacher educators must help prospective teachers prepare themselves for these kinds of tasks.

A major way to prepare teachers for innovation is to help them develop inquiry skills that support ways to look at student learning and adapt accordingly. Many of the chapters in this book emphasize inquiry. Inquiry represents a very different way of learning than simply memorizing facts about teaching and learning strategies without understanding why and when they are relevant.

Another way to prepare teachers to become adaptive experts is to help them explore where different theories of learning fall with respect to the efficiency and innovation dimensions. For example, many people contrast Thorndike (a behaviorist who emphasized trial-and-error learning and efficiency) and Dewey (a progressivist who liked projects and discovery) and argue about who is right. An alternative way to think about this issue is to assume that the choice is not one of "either/or." Thorndike's work falls primarily on the efficiency dimension in Figure 2.1 and Dewey's is closer to the innovation dimension. A conjecture currently being explored by learning scientists is that it is the balance among these that supports adaptive expertise (see, for example, Schwartz, Bransford, and Sears, in press).

Preparing Teachers to Understand and Support Learning

An important part of teacher preparation is to help people become familiar with technical concepts that support understanding—concepts such as summative versus formative assessment, normative versus criterion-based testing, pedagogical content knowledge, routine versus adaptive expertise, behavioral theory versus Piagetian theory, and so forth. But research on learning shows that people need much more than facts (for example, declarative knowledge) if the goal is to help them act and reflect responsibly. There are a number of strategies that teacher educators have developed to help preservice teachers understand and be able to thoughtfully apply the important ideas and concepts about learning discussed in this chapter, and these often emulate the strategies that research has found to be useful in developing *students'* learning—strategies that develop teachers' capacity to be adaptive experts who can take nonroutine aspects of the context into account in making sound teaching decisions.

Teachers can certainly profit from some direct instruction about broad principles of learning that may be highly generalizable, like many of those we have outlined in this chapter. At the same time, however, teachers also need to know that general theories of learning, although they provide guidelines for the design of effective learning environments, cannot produce a single recipe to use in all situations. One of the key features of modern learning theory is that optimal learning environments must be tailored to specific learning goals, to the students' backgrounds and prior knowledge, and to the contexts in which learning will occur. Thus teachers not only need to understand basic principles of learning but must also know how to use them judiciously to meet diverse learning goals in contexts where students differ in their needs.

Teachers' work is not unlike that of engineers building a bridge, who must not only understand principles of physics needed for safe structures and tricks of the trade (such as how to block off the water so that cement foundations can be poured); they must take into account the nature of the terrain, the overall length of the bridge, the uses to which it will be put and how much weight it must support, the nature of materials available for construction, the aesthetics of the design favored by the surrounding community, and whether there are earthquakes, floods, or other events common to the area. Like the engineers in this example, teachers need to learn how to evaluate the salience of many different conditions that influence learning and the potential effectiveness of different teaching strategies as they make decisions about what to do in particular instances.

To do this, teachers need to develop a conceptual map of the domain of influences on learning (including both contextual influences and the impacts of different teaching strategies), and they need to develop means for evaluating how these may be operating in specific instances. The *How People Learn* framework provides one way of organizing such a conceptual map. There are, of course,

others as well. What is key is that teachers learn not just discrete facts about specific learning theories but a framework for the field as a whole. They also need analytic skills for interpolating between specific, highly contextualized teaching and learning events and general theories that can prove useful in interpreting them and providing guidance for how to proceed.

Among the specific pedagogies teacher educators have developed to help preservice teachers understand learning in relation to teaching are analyses of learning through careful observation of students and their work, analyses of novice teachers' own attempts to teach, and self-reflection on their own learning. Increasingly, these strategies ask teachers to examine teaching *in the light of learning* rather than simply asking teachers to implement discrete teaching behaviors culled either from theoretical principles or from studies about practices that were sometimes correlated with student achievement.

Quite often, research has found that strategies used successfully in one context have been less successful in others, or that overused, particular approaches prove much less effective, or that the mix of strategies is important, not just a single tactic by itself. For example, the degree of structuring or kind of scaffolding that is optimal for learning tasks depends in part on students' prior experiences and familiarity. How teachers *combine* inquiry-oriented learning and direct instruction is important for understanding, not just either alone. And the representations teachers choose will be most effective if they tap particular students' background knowledge. These contingencies are key for teachers to understand. Teacher education pedagogies that attend to how learning actually happens and how teaching actually affects learning for different students contrast with the older "technicist" era of teacher training, in which teaching was seen as the implementation of set routines and formulas for behavior, unresponsive to the distinctive attributes of either clients or curriculum goals (Darling-Hammond, 2001a). Examples of some of these emerging pedagogies are provided in the following discussion.

Developing a Conceptual Framework for Analyzing Learning and Teaching

An important way that teacher educators help new teachers understand and appreciate some of the complex factors at play in teaching and learning is to engage prospective teachers in the analysis of teaching and learning. Prospective teachers can examine videotapes of teachers, student work samples, teaching plans, assessments, and other materials from classrooms to help them attend more closely to the nature, focus, and character of the learning they demonstrate.

To make sense of learning, it is helpful for prospective teachers to develop a conceptual framework of influences on learning; to be able to identify and question their assumptions about learning, both in general and in specific instances; and to be able to organize their own inquiry process. One approach to developing these abilities was developed at Vanderbilt University by a group of instructors interested in applying both learning theory and technology to the preparation of teachers (PT3 Group at Vanderbilt, 2003). The AMIGO project uses the four lenses of the *How People Learn* framework as the basis for technology-based learning modules organized around challenges that trigger an inquiry process for the prospective teachers. The modules are designed to capitalize on what is known about how people learn through guided inquiry while also teaching the students about how people learn. A goal is to help the students learn to balance all four of these lenses simultaneously when they think about the learning process and the design of instruction by having them both study these ideas and experience them. (See "Developing a Conceptual Framework for Teaching and Learning.")

Developing a Conceptual Framework for Teaching and Learning

In the *How People Learn* course designed through the AMIGO project, the goal is for prospective teachers to look at learning situations and integrate knowledge through the four lenses of the framework—considerations of knowledge, learners, community, and assessment—in developing teaching responses. The challenges—questions like, "How could a test become a gift?" and "What shall we do about Bob?" (see earlier discussion in this chapter)—are the basis for students to first identify their initial thoughts, which are published to the Web, and then use resources that are available on-line (readings, audio and video clips of experts and teachers, simulations, suggestions for hands-on activities) to develop a deeper understanding of the issue, followed by a self-assessment of understanding (via tests that are provided or essays that receive feedback.) When they feel ready, students "go public" with a written essay or class presentation about what they have learned. Or they may construct challenges of their own for others to try. Students compare their thinking to their initial ideas. They may also respond to each other's answers to create a wider community of learning that provides access to multiple perspectives on the topic.

Research was conducted on the outcomes of one such class, taught on-line and in person using thirty-five modules developed to accompany the *How People Learn* text from the National Research Council. The goals of the course were to help students learn to analyze teaching and learning using the framework in order to evaluate the instruction of others as well as to design and assess their own instruction. The course strategies included inquiry using the on-line resources and others the students sought out, along with on-demand mini-lectures in class or on the Web that instructors designed to respond to students' questions and learning needs as these were revealed in their postings to the challenges and class conversations on the Web.

Pre- and post comparisons of students' initial and later responses to the challenges provided substantial evidence of learning throughout the course. Most interesting were students' own analyses of their learning. As one wrote of the "test as a gift" challenge,

> Reviewing my initial response to this challenge was great because I think that this one really shows how much I have progressed in a semester regarding my understanding . . . I wrote, "How could a test be made positive? I do not know . . ." This is very exciting because I have since learned tons about formative assessment and have many ideas regarding "tests." Being in the class really caused me to question what a function of a test is. Partly, it is to hold teachers and students accountable, but additionally, and more importantly, it is to give students the opportunity to grow. Tests can be exciting; they can be "learner friendly" so to speak. The challenge asked the question, "How can a test be made like a gift?" My answers now is, "By giving students formative 'tests' or assessments. By providing students with opportunities to revise and improve their thinking, they are helped to identify problems and see their own progress, which is encouraging and worthwhile." (PT3 Group at Vanderbilt, 2003, p. 114)

The prospective teacher's perspective on what she would do to enhance her students' learning mirrored what she had just experienced in developing and refining her own ideas.

In another example of how analyses of learning situations can be used to reinforce the development of a conceptual framework, prospective teachers at Stanford University view videotapes of contrasting classrooms and are asked to write an analysis of them using the four lenses of the HPL framework. They examine how each classroom attends to knowledge, learners, community, and assessment in the process of teaching and how this influences learning. While watching the tapes, the student teachers need to take careful notes on the interactions they observe (in brief, field-note style) noting the setup of the classroom, jotting down direct quotes from the teacher and the children. These field notes comprise their perceptions and observations. The student teachers are then asked to consider what they observed in light of each element of the framework. How does the teacher organize the *knowledge* to be acquired so that it is accessible? In what ways does the teacher engage *learners'* interests and connect to their prior knowledge, experiences, and ideas? How does the teacher construct a *community* in the classroom? How does the teacher *assess* what the students know and are learning? Finally, the student teachers must evaluate the way in which the teacher scaffolds the learning process. What specific steps does the teacher take to ensure that learners are able to understand the material to be learned?

Completing this assignment helps prospective teachers look carefully at particular interactions between children and teacher. For instance, in an assignment using videotapes of a Japanese mathematics teacher from the Third International Mathematics and Science Study (TIMSS) tape, student teachers notice the careful selection of a challenging and authentic geometry problem for the class that opens up the mathematical questions effectively (knowledge-centered), as well as the way the teacher engages the students by using their names and personal interests in soliciting initial guesses to the problem (learner-centered). Prospective teachers often write about the way that the students are encouraged to work together to solve the problem and often remark upon how comfortable the students appear in coming to the board to present their particular approach to the problem in front of their peers (community-centered). Many student teachers write about the ways in which the students' presentations of different solutions make mathematical thinking visible to others (the teacher and other classmates), and some recognize the ways in which that approach actually reflects the academic mathematics community values of debate, discussion, and demonstration of methods (knowledge-centered). Finally, many notice the ways in which the teacher's emphasis upon public discussion and evaluation of a variety of students' solutions enables him to continually assess his students' current thinking and understanding (assessment-centered).

When asked to apply the HPL framework in this way on multiple occasions, it becomes a tool that enables prospective teachers to better understand what supports learning and how to design instruction. This kind of assignment helps new teachers begin to use the ideas and develop their own conceptual framework for organizing key ideas about learning—rather than simply memorize disconnected elements that remain abstractions.

Examining Learning in Relation to Teaching

Often, analyses of teaching have focused more on what teachers *do* than on what students *learn*. In recent years, there has been a great deal more emphasis on asking teachers to evaluate student work and learning together so that they can begin to understand the outcomes of instruction and to think about what would need to change to achieve stronger outcomes. Some teacher educators have begun to capitalize on such approaches by designing assignments that ask prospective teachers to collect evidence about student learning and to examine it in relation to the teaching that leads to it. One such strategy asks student teachers to collect three different kinds of evidence about student learning using different methods; for example, a test or formal essay, a free-write from the student about what she or he believes she has learned, an interview of the student about the material, or a performance in which the student is asked to apply the content to a new problem. The student teachers must then compare what can be inferred from these different methods about what the student did or did not appear to learn or understand, and to consider this in relation to the kind of teaching that the student experienced.

This kind of fine-grained evaluation of learning in relation to teaching raises questions about the learning process and the individual learner, the nature of different assessments and what they reveal or conceal, the kinds of knowledge sought and achieved, and the learning context. These questions can then be explored in more detail and connected to discussions of learning theory and instructional design. In addition, this kind of strategy sensitizes prospective teachers to the many aspects of learning, teaching, and assessment that can make a difference in the outcomes of their efforts.

Some teacher educators have found that asking teachers to write cases about teaching and learning can be particularly helpful. Case writing can focus teachers upon gathering evidence of learning, which pushes them to begin to articulate and understand what learning looks like (and does not) for their students and in their subject matter. Case writing can also be particularly helpful in aiding new teachers in analyzing how teaching contexts and approaches influence learning in the context of their own practice.

As an illustration, prospective teachers taking a course on Principles of Learning for Teaching at Stanford University write a "curriculum case" in which they detail the events of a learning segment (it can be a lesson that occurred over the course of a day or several days) and analyze it in light of learning theory (for details, see Hammerness, Darling-Hammond, and Shulman, 2002). Most critical to novices' ability to produce a powerful case is the use of evidence of learning combined with readings and discussions about learning theory. For the case, student teachers must not only describe what they did and said as teachers, but they are also asked to focus in particular upon how *their* students responded and what they learned, both individually and collectively. They must include substantive evidence of student learning, which can be in the form of samples of student work (essays, problem sheets, lab reports, and so on), transcriptions of classroom discussions, quotes from students, and even descriptions of the body language and other behaviors of their students. Student teachers then analyze this evidence after having described the learning context, the students whom they teach, their goals and intentions, and their instructional actions in order to consider the relationship between what they hoped for, what they did, and what their students learned (or didn't learn, as the case may be).

Quite often this exercise creates a common epiphany about the learning process, one in which student teachers see many of the learning principles they have been studying in action. For instance, one science teacher wrote her curriculum case about her unit on evolution and focused upon the difficulty of helping her high school students overcome Lamarckian conceptions of evolution. She noted that on the first day on this topic, their comments seemed to indicate that they immediately understood Darwin's theory. But a test on the concept (as well as comments she recorded from a later discussion) illustrated that misconceptions and misunderstandings about evolution still dominated in the class, even among some of her most accomplished students. The case author was disappointed and puzzled—if they understood Darwin's theory (even laughing at some of the Lamarckian interpretations of evolution), then why did they do so poorly on the exam?

By analyzing the evidence of learning she had collected for her case, she was able to identify the ways in which students' prior knowledge and commonsense explanations had interfered with the new disciplinary knowledge they had encountered in the class (a sophisticated rendering of the same *Fish is Fish* learning problem we discussed earlier in this chapter). Using key ideas from the course on learning, including ongoing assessment, metacognition, and prior knowledge, she was then able to identify some strategies she could use in the future to lead her students to more theoretically sound explanations and to more robust and deeper understandings of evolution. For instance, she discussed how she could have used a quick initial written assessment to determine how well the students understood after the first day and to test their growing understanding. That assessment would have probably revealed some of the misunderstandings and misconceptions that she did not encounter until later. She also suggested that a different summative assessment (an essay, instead of the test she had used) would also have pushed her students be more articulate about the differences between the two theories. She argued that if she had asked the students to compare and contrast the theories in writing, her students might have been able to attend to the more subtle but important distinctions (as well as some of the ways in which Lamarck's theory is intuitively appealing) and to be more thorough and careful in their presentation of the theories. (To read this case and examples of cases written by other prospective teachers, visit the Web site from the course: http://kml2.carnegiefoundation.org/gallery/khammerness/c_in_the_c/final/archive/archive.html.)

It is important to emphasize that these cases were the result of careful thinking and analysis over the course of several drafts, including feedback from peers and instructors and several "conferences" in which student teachers discussed emerging interpretations. Research analyzing the cases written for the course demonstrated that through the case-writing process, student teachers moved from naïve generalizations about their students' learning (students didn't "get it"; students hadn't tried hard enough; the teachers needed more time) to more expert, theory-based interpretations of the learning process (Hammerness and others, 2002). Through these case analyses, student teachers were able to begin to make distinctions about the nature of learning, what learning "looks like," and how to support and assess it—understandings that are critical to helping prospective teachers think about learning in much more complex terms than just a "lightbulb" in students' heads.

Developing Metacognition by Reflecting on Learning

Experiences like case writing and analyses of learning may be made even more effective if student teachers have also had an opportunity to think about and reflect upon their own learning experiences. New teachers who have had little experience with children or in teaching roles before coming to teacher education may benefit even more from such experiences. Reflecting on their

own learning can also help new teachers take a first step in making their own assumptions about teaching and learning explicit—a key part of then critically examining them, as we have discussed in this chapter.

At San Jose State University in a course on learning, one teacher educator's first assignment asks prospective teachers to describe both a very powerful learning experience (either in or out of school) and a learning experience that was less successful, and then to compare and contrast the two. The students are not only required to describe these experiences, but also to analyze them to identify key characteristics of good learning experiences as well as poorer ones. In many programs, student teachers may be asked questions like the following as the basis for written reflections: "In general, what learning conditions and teaching strategies do you think most enable you to learn effectively? Think back to a specific time when you tried to learn something but felt you could not deeply understand it or become proficient. What was the nature of the learning situation? What impeded your learning? How did you feel? Can you imagine what would have allowed you to learn more effectively? Now think back to a time when you successfully learned something that was especially challenging. What was the nature of the content or skill that you were trying to learn? What made it difficult? What finally enabled you to succeed in mastering these difficult ideas or skills?"

Once students have had an opportunity to identify some of the key characteristics of good learning experiences in their own educational history, they are often more prepared to make sense of what they learn in their teacher preparation program about learning. Concepts of the zone of proximal development may have more depth when student teachers themselves have thought about how, for example, they learned to fix cars with their father over the course of several years. Concepts like metacognition have more power when teachers, for instance, have a chance to write about how opportunities to discuss the strengths and weaknesses of their writing with a supportive teacher helped them learn to write well. And in turn, student teachers are often able to appreciate better the nature of good learning experiences for their own students after having an opportunity to be metacognitive themselves about their own experiences.

In addition, courses for preservice teachers may be even more effective if they include opportunities to monitor their own learning in the course, to help them appreciate how thinking about one's own learning can facilitate greater understanding. For instance, in both the *How People Learn* course at Vanderbilt and the *Principles of Learning* course at Stanford, students were asked to write a reflection about their own learning after they completed a challenge or wrote a curriculum case. This allowed them both to gain more insights about their own learning and to give feedback to the instructors about what was useful, what could be more useful, and what more they wanted to learn.

Because prospective teachers' personal learning experiences are powerful predictors of their own teaching practices, the ways in which teacher educators model practices that are productive for learning is critically important. Student teachers will reflect on what they have encountered whether invited to or not, and they will draw implicit conclusions from their experience. Quite often teachers have in the past complained about preparation or professional development settings in which an instructor lectures them about the need to use cooperative learning techniques or tests them on formative and summative assessment principles without providing opportunities for constructive feedback and revision. Throughout the teacher education program, and especially in courses on learning, it is crucial that student teachers be asked to learn in ways that reflect what they are being taught about how people learn.

Connected Knowledge and Program Coherence

The discussion of expertise in the earlier part of this chapter emphasized the importance of well-connected knowledge that is organized around "big ideas" of the disciplines. For example, we noted that the concept of life cycles can be learned as a set of isolated facts (for example, students memorize the life cycle of some organism) or as an organizing principles that provides a basis for thinking about a variety of issues, including ways to prevent species from becoming endangered, ways to intervene to control pests, and so forth. Books like *Understanding by Design* (Wiggins and McTighe, 1998) provide important guidelines for "working backwards" by first identifying the enduring ideas of a discipline and then choosing particular strategies for instruction and assessment (see also Bruner, 1960/1977).

Teacher preparation programs need to consider issues of connected knowledge at the level of individual course design and at the level of the design of entire programs of study (including integration between college courses and classroom-based experiences). The second issue is often referred to as "program coherence," and it represents a challenge for all professional programs. Especially important is the degree to which *students* are able to understand how everything fits together, not simply the faculty. This set of issues is discussed in more detail in Chapter Eleven.

CONCLUSION

Concepts of learning (including ideas about transfer) are central to all attempts to improve education. Everyone has theories of learning, although they often remain tacit. We make assumptions about what is important to learn, who can learn, how to help people learn, and how to assess learning. By making tacit theories explicit, teachers can continually evaluate their assumptions and improve throughout their careers.

The concepts and theories in this chapter provide a way to begin to think about learning. By exploring these core ideas, prospective teachers can learn to identify many forms of evidence of learning, can appreciate how to evaluate and assess it, and finally, with support, can understand how to recognize and put into practice the features of classrooms that best support the kinds of learning they seek. Ideally, conceptualizations about learning can also provide a basis for connecting all of the important areas of expertise that teachers need to develop to help all students succeed.