Chapter 3

Rethinking Transfer: A Simple Proposal With Multiple Implications

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A belief in transfer lies at the heart of our educational system. Most educators want learning activities to have positive effects that extend beyond the exact conditions of initial learning. They are hopeful that students will show evidence of transfer in a variety of situations: from one problem to another within a course, from one course to another, from one school year to the next, and from their years in school to their years in the workplace. Beliefs about transfer often accompany the claim that it is better to "educate" people broadly than simply to "train" them to perform particular tasks (e.g., Broudy, 1977).

In this chapter, we discuss research on transfer from both a retrospective and a prospective perspective. What has past transfer research taught us that is especially important for education? What might research on transfer look like in the future? Our discussion of past research is brief, not because it is unimportant but because of space limitations and the fact that our primary emphasis is on the future. We argue that prevailing theories and methods of measuring transfer are limited in scope; we propose an alternative that complements and extends current approaches; and we sketch this alternative's implications for education.

Our discussion is organized into five sections. First, we briefly summarize some of the key findings from the literature on transfer—both the successes and the disappointments. Second, we contrast the "traditional" view of transfer with an alternative that emphasizes the ability to learn during transfer. Third, we discuss mechanisms for transfer that emphasize Broudy's analysis of "knowing with" (which he adds to the more familiar replicative "knowing that" and applicative "knowing how"). Fourth, we show how our alternate view of transfer affects assumptions about what is valuable for students to learn. Finally, we show

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how our view encourages a dynamic (rather than static) approach to assessment that can provide new insights into what it means to learn.

RESEARCH ON TRANSFER: ECSTASIES AND AGONIES

One of the most important benefits of research on transfer is the window it provides on the value of different kinds of learning experiences. A particular learning experience may look good or poor depending on the testing context (e.g., Morris, Bransford, & Franks, 1977). Different kinds of learning experiences can look equivalent given tests of memory yet look quite different on tests of transfer (see Figure 1). Measures of transfer provide an especially important way to evaluate educational success.

In this section, we briefly summarize contributions from research on transfer that are particularly relevant to education. We then discuss some of the disenchantments with the transfer literature.

Contributions From Research on Transfer

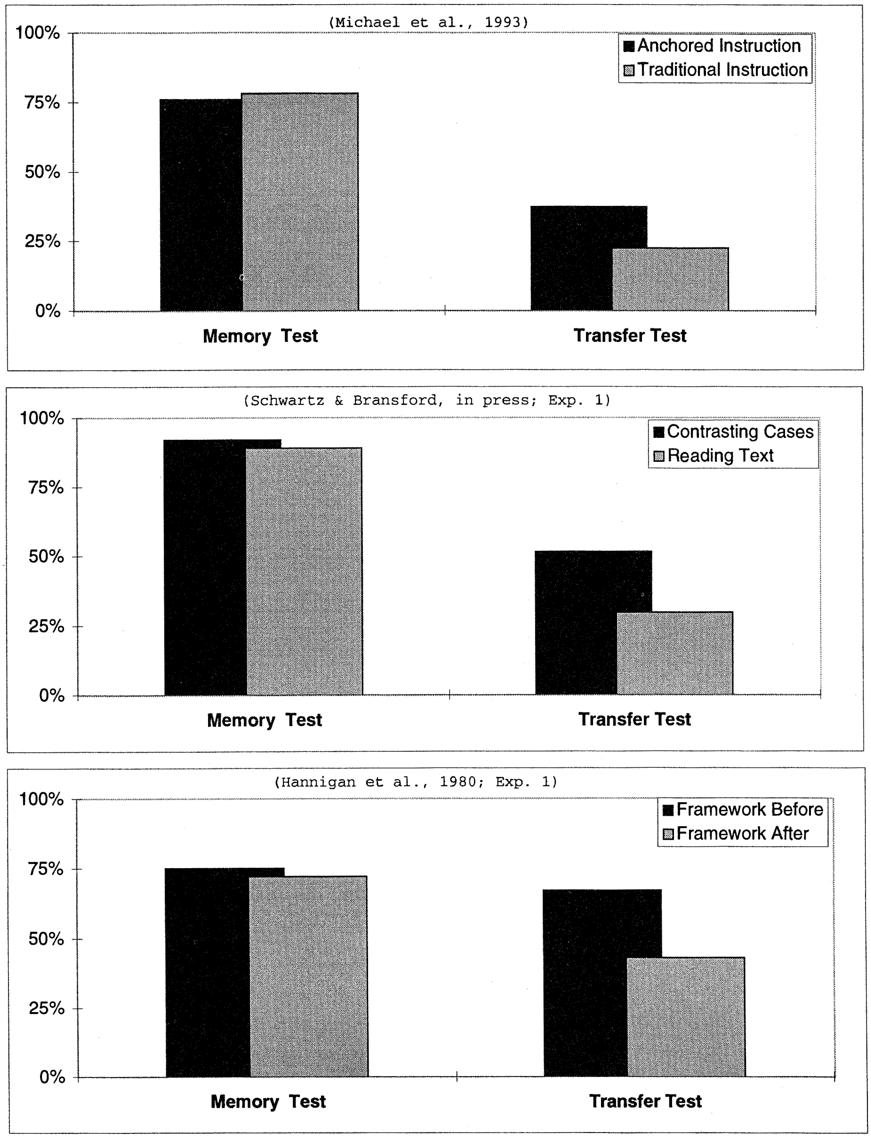
Thorndike and his colleagues were among the first to use transfer tests to examine assumptions about the benefits of learning experiences (e.g., Thorndike & Woodworth, 1901). One goal of their research was to challenge the doctrine of "formal discipline" that was prevalent at the turn of the 20th century. Practice was assumed to have general effects; for example, people were assumed to increase their "general skills of learning and attention" by learning Latin or other taxing subject matters. Discussions of assumptions about formal discipline date back to the Greeks (see Mann, 1979). Challenging these assumptions, Thorndike's work showed that even though people may do well on a test of the specific content they have practiced, they will not necessarily transfer that learning to a new situation.

Thorndike and colleagues' studies raised serious questions about the fruitfulness of designing learning environments based on assumptions of formal discipline. Rather than developing some type of "mental muscle" that affected a wide range of performances, people seemed to learn things that were very specific. As Thorndike and Woodworth (1901) stated:

> The mind is . . . a machine for making particular reactions to particular situations. It works in great detail, adapting itself to the special data of which it has had experience. . . . Improvement in any single mental function rarely brings about equal improvement in any other function, no matter how similar, for the working of every mental function group is conditioned by the nature of the data of each particular case. (pp. 249–250)

Thorndike and his colleagues helped establish an important tradition of examining assumptions about learning and transfer through rigorous experimental research. During the past century, researchers have discovered a number of important principles about the conditions of learning that enhance and impede transfer. We briefly discuss some of the findings that are particularly relevant

FIGURE 1
Examples of Studies Showing That Transfer Tests Can Be More Sensitive Measures of Different Learning Experiences Than Memory Tests



to education (more extended discussions can be found in Anderson, Reder, & Simon, 1997; Detterman & Sternberg, 1993; and Lee, 1998).

One important finding from research is that effective transfer requires a sufficient degree of original learning. Although this seems obvious, a number of claims about "transfer failure" have been traced to inadequate opportunities for people to learn in the first place (e.g., see Klahr & Carver, 1988; Lee, 1998; Lee & Pennington, 1993; Littlefield et al., 1988). The degree to which learning has made the retrieval of relevant knowledge ''effortful'' or relatively ''effortless'' also affects transfer (e.g., Beck & McKeown, 1983; Hasselbring, Goin, & Bransford, 1987, 1988). Without attention to degree of original learning, people can erroneously conclude that potentially helpful educational programs are ineffective.

The manner in which information is learned also affects subsequent transfer. Judd's classic studies of learning to throw darts at underwater targets demonstrated the value of learning with understanding rather than simply mimicking a set of fixed procedures (cf. Judd, 1908). Wertheimer (1959) compared instruction that focused on a computational versus conceptual approach to determining the area of parallelograms and demonstrated how the conceptual approach facilitated transfer to new problems. Bransford and Stein (1993, chap. 7), Brown and Kane (1988), and Chi et al. (1989; Chi, Slotta, & deLeeuw, 1994) explored how learning with understanding is important for enhancing performance on subsequent transfer tasks. Studies also show that information presented in the context of solving problems is more likely to be spontaneously used than information presented in the form of simple facts (e.g., Adams et al., 1988; Lockhart, Lamon, & Gick, 1988; Michael et al., 1993; Sherwood et al., 1987).

Researchers have also explored the effects of using concrete examples on learning and transfer. Concrete examples can enhance initial learning because they can be elaborated and help students appreciate the relevance of new information. In addition, learning potentially confusable concepts in different contexts can protect people from interference during the initial trials of learning (cf. Bransford et al., 1990). However, despite its benefits for initial learning, overly contextualized information can impede transfer because information is too tied to its original context (e.g., Bjork & Richardson-Klahaven, 1989; Gick & Holyoak, 1980). Presenting concepts in multiple contexts can increase subsequent transfer (e.g., Gick & Holyoak, 1983; cf. Bransford et al., 1990).

Proponents of case-based, problem-based, and project-based learning (e.g., see Barron et al., 1998; Barrows, 1985; Cognition and Technology Group at Vanderbilt [CTGV], 1997; Hmelo, 1994; Williams, 1992) attempt to deal with problems of overcontextualization in a number of ways, including presenting similar materials in multiple contexts, having students engage in ''what if'' problem solving that prompts them to think about the qualitative effects of varying particular problem parameters (CTGV, 1997), and changing the nature of the problems to ones in which students are asked to invent solutions to a broad class of problems rather than simply attempt to solve only a single problem (e.g., Bransford et al., 1999; CTGV, in press). Viewing problem environments from multiple perspectives also increases the flexibility with which people can deal with new sets of events (e.g., Bransford et al., 1990; Spiro et al., 1987).

Related to issues of overcontextualization is the issue of helping people represent problems and solutions at appropriate levels of abstraction. Appropriate problem representations increase positive transfer and decrease the probability of negative transfer (for discussions of negative transfer, see Chen & Daehler, 1989; Luchins, 1942; Singley & Anderson, 1989). For example, students solving CTGV's Jasper adventure "The Big Splash" learn to use statistical information to create a complex business plan (see CTGV, 1997). Ultimately, they need to realize that their solution works well for "fixed cost" problems but not for those in which costs are not fixed. Without this more general understanding, they apply their knowledge in the wrong settings. Informative studies about helping students create effective problem representations for transfer include Singley and Anderson (1989) and Novick (1988).

An emphasis on metacognition (e.g., Brown, 1978; Flavell, 1976)—on helping students monitor, reflect upon, and improve their strategies for learning and problem solving—has also been shown to increase transfer. Examples include learning in the areas of science (e.g., Lin et al., 1995; White & Fredrickson, 1998), mathematics (e.g., CTGV, 1994; Schoenfeld, 1985), computer programming (Bielaczyc et al., 1995), and literacy (e.g., Palincsar & Brown, 1984; Pressley & Afflerbach, 1995). Research also suggests that metacognitive activities such as comprehension monitoring have strong knowledge requirements; they are not general skills that people learn "once and for all." For example, without well-differentiated knowledge of the performance requirements of a particular task (e.g., monitoring a river for water quality), people cannot accurately assess whether they are prepared to perform that task (e.g., see Vye et al., 1989).

Disenchantments With the Transfer Literature

Even the preceding brief review illustrates that research has provided some fundamental insights into the kinds of learning experiences that promote transfer. Nevertheless, there is also considerable disenchantment with the transfer literature. One set of criticisms comes from proponents of "situative cognition" who argue that cognitive theorists need to redefine their approach to transfer (see especially Greeno, 1997; Lave, 1988). Even within the cognitive tradition, researchers have worried that transfer is too hard to find—that there are too many examples of transfer failure. The title of a recent book, *Transfer on Trial*, illustrates this point (Detterman & Sternberg, 1993). In the volume's introductory chapter, Detterman presents "the case for the prosecution" and provides the following analysis of the transfer literature:

> First, most studies fail to find transfer. Second, those studies claiming transfer can only be said to have found transfer by the most generous of criteria and would not meet the classical definition of transfer [defined by Detterman as "the degree to which a behavior will be repeated in a new situation"; p. 4]. . . . In short, from studies that claim to show transfer and that don't show transfer, there is no evidence to contradict Thorndike's general conclusions: Transfer is rare, and its likelihood of occurrence is directly related to the similarity between two situations. (p. 15)

Not all theorists are as pessimistic about transfer as is Detterman (e.g., see the other contributors to Detterman & Sternberg, 1993). Nevertheless, there are enough examples of transfer failure to consider positive transfer to be at least a relatively rare event according to the criterion of repeated behavior.

Broudy (1977) also discusses the difficulty of consistently finding evidence of transfer. His focus is on evidence of the benefits of formal education for future thinking and problem solving:

> Ever since formal schooling was established, it has been assumed that knowledge acquired in school would be used to enhance the quality of human life. The investment in schools was supposed to yield a return in the form of greater adequacy in occupational, civic, and personal development. (p. 2)

Broudy notes that people rapidly forget the facts that they learned in school, as might be measured by tests of "replicative knowing." He also concedes that most people have difficulty applying their knowledge in order to solve new problems, or what he calls "applicative knowing." He concludes that school is a failure based on replicative and applicative tests of learning. But, as discussed later, Broudy's conclusion is not that transfer is rare. Instead, his work points to the need to rethink our ideas of what it means to learn and to know and how we evaluate educational experiences.

In line with Broudy, we argue for the need to reconsider some of the prevalent beliefs about what constitutes a valuable demonstration of transfer. Our thesis is that evidence of transfer is often difficult to find because we tend to think about it from a perspective that blinds us to its presence. Prevailing theories and methods of measuring transfer work well for studying full-blown expertise, but they represent too blunt an instrument for studying the smaller changes in learning that lead to the development of expertise. New theories and measures of transfer are required.

As an illustration, consider a set of studies conducted by Kay Burgess, Sean Brophy, and the present authors. In one study, we asked fifth graders and college students to create a statewide recovery plan to protect bald eagles from the threat of extinction. Our goal was to investigate the degree to which their general educational experiences prepared them for this novel task; none of the students had explicitly studied eagle recovery plans.

The plans generated by both groups missed the mark widely. The college students' writing and spelling skills were better than those of the fifth graders, but none of the college students mentioned the need to worry about baby eagles imprinting on the humans who fed them, about creating tall hacking towers so that fledgling eagles would imprint on the territory that they would eventually call home, and about a host of other important variables. In short, none of the students generated a recovery plan that was even close to being adequate. On the basis of these findings, one might claim that neither the fifth graders' nor the college students' general educational experiences prepared them adequately for transfer.

However, by another measure of transfer, the differences between the age groups were striking. We asked the students to generate questions about important issues they would research in order to design effective recovery plans for eagles (see the Appendix). The fifth graders tended to focus on features of individual eagles (e.g., How big are they? What do they eat?). In contrast, the college students were much more likely to focus on issues of interdependence between the eagles and their habitats. They asked questions such as ''What type of ecosystem supports eagles?'' (reflecting an appreciation of interdependence), ''What about predators of eagles and eagle babies?'' (also reflecting interdependence), ''Are today's threats like the initial threats to eagles?'' (reflecting an appreciation of history and change), and ''What different kinds of specialists are needed for different recovery areas?'' (reflecting an appreciation of a possible need for multiple solutions). Because they had not studied eagles directly, the college students were presumably generating questions framed by other aspects of biology that they had learned. So, by this alternative form of transfer test, it would appear that the college students had learned general considerations that would presumably help shape their future learning if they chose to pursue this topic (Scardamalia & Bereiter, 1992). In this regard, one would call their prior learning experiences a success.

In the discussion to follow, we explore what we consider the ''traditional'' view of transfer and contrast it with an alternative view that has important implications for educational research and practice. The alternative we propose is not something that we have invented—it too exists in the literature. However, the contrast between it and the ''traditional'' view has not been emphasized as much as it might be, and the implications for educational practice have not been explicitly explored.

TWO VIEWS OF TRANSFER

Central to traditional approaches to transfer is a dominant methodology that asks whether people can apply something they have learned to a new problem or situation. Thorndike and colleagues' classic studies of transfer used this paradigm. For example, in Thorndike and Woodworth (1901), participants took a pretest on judging the area of rectangles and then were given opportunities to improve their performance through practice plus feedback. Following this learning task, participants were tested on the related task of estimating the areas of circles and triangles. Transfer was assessed by the degree to which learning skill *A* (estimating the area of squares) influenced skill *B* (estimating the area of circles or triangles). Thorndike and Woodworth found little evidence of transfer in this setting and argued that the ''ability to estimate area'' was not a general skill.

Gick and Holyoak's (1980, 1983) work on analogical transfer provides a modern-day example of a similar paradigm for studying transfer. Participants in their studies first received information about a problem and a solution, such as ''the general and the fortress problem.'' They then received a second problem (Duncker's [1945] irradiation problem) that could be solved by analogy to the first problem. Depending on the conditions of the experiment, participants either did or did not show evidence of applying what they had learned about the general's solution to solve the irradiation problem. In many instances, there was a surprising failure to transfer spontaneously from one problem to the next. Many other researchers use a similar paradigm of initial learning followed by problem solving (e.g., Adams et al., 1988; Bassok, 1990; Brown & Kane, 1988; Chen & Daehler, 1989; Lockhart, Lamon, & Gick, 1988; Nisbett, Fong, Lehman, & Cheng, 1987; Novick, 1988; Perfetto, Bransford, & Franks, 1983; Reed, Ernst, & Banerji, 1974; Thorndike & Woodworth, 1901; Wertheimer, 1959).

A striking feature of the research studies just noted is that they all use a final transfer task that involves what we call "sequestered problem solving" (SPS). Just as juries are often sequestered in order 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). Our thesis is that the SPS methodology and the accompanying DA theory of transfer are responsible for much of the pessimism about evidence of transfer.

An alternative to SPS methodology and DA theory is a view that acknowledges the validity of these perspectives but 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 do not 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 (e.g., texts, computer programs, colleagues) to facilitate this learning. The better prepared they are for future learning, the greater the transfer (in terms of speed and/or quality of new learning).

As an illustration of transfer as PFL, imagine elementary education majors who graduate and become classroom teachers for the first time. By the standard DA definition of transfer, the test of transfer would be whether the beginning teachers, without coaching, can apply to the classroom the methods they learned in school. As noted earlier, this is an important concern, yet it is only one part of the larger story. The larger story involves whether the novice teachers have been prepared to learn from their new experiences, including their abilities to structure their environments in ways that lead to successful learning (e.g., arrange for peer coaching). There is no preliminary education or training that can make these people experts; it can only place them on a trajectory toward expertise.

A focus on transfer from the perspective of its effects on new learning is not an idea that is unique to us; the idea has been discussed and studied by many theorists (e.g., Bereiter, 1990; Bereiter & Scardamalia, 1993; Glaser & Chi, 1988; Gott et al., 1992; Greeno, Smith, & Moore, 1993; Lee, 1998; Lee & Pennington, 1993; Singley & Anderson, 1989; Spiro et. al, 1987; Wineburg, 1998). Nevertheless, as we worked on this chapter, we realized that our thoughts about the two perspectives were not well differentiated; we switched from one view to the other without realizing the shift in our thinking. We have come to believe that this lack of differentiation is not unique to us and that it is worthwhile to contrast these two views of transfer explicitly because they have different implications for educational practice.

One important difference is that the PFL perspective helps us notice evidence of positive transfer that is often hidden in the traditional SPS paradigm. Studies in the area of skill acquisition illustrate this point. Researchers such as Singley and Anderson (1989) have asked how experience with one set of skills (e.g., learning a text editor) affects people's abilities to learn a second set of related skills (e.g., a second text editor). These studies used what we are calling a PFL paradigm; the focus was on students' abilities to learn the second program as a function of their previous experiences. Data indicate that the benefits of previous experiences with a text editor did not reveal themselves immediately. The researchers found much greater evidence of transfer on the second day than on the first. One-shot SPS tests of transfer are often too weak to detect effects such as these.

As we describe later in the section on assessment, the ideal assessment from a PFL perspective is to directly explore people's abilities to learn new information and relate their learning to previous experiences (e.g., see Brown, Bransford, Ferrara, & Campione, 1983; Bruer, 1993; Singley & Anderson, 1989). However, more standard SPS tasks can sometimes be reinterpreted from a PFL perspective. The PFL perspective helps counter the tendency of SPS methodologies and DA theories to focus primarily on deficiencies in problem solving when novice learners are compared with experts. In the study on eagles described earlier, the SPS assessment revealed how far the fifth-grade and college students were from developing an adequate eagle recovery plan, and it invited the inference that the students' K–12 experiences had not prepared them for this kind of transfer. From the PFL perspective, one looks for evidence of initial learning trajectories. So, rather than an evaluation of whether people can generate a finished product, the focus shifts to whether they are prepared to learn to solve new problems. For example, one determinant of the course of future learning is the questions people ask about a topic, because these questions shape their learning goals (e.g., see Barrows, 1985; Bereiter & Scardamalia, 1989; Hmelo, 1994). In the eagle experiment, the PFL perspective yielded a deeper appreciation of how the college students' K–12 experiences had prepared them to learn.

TRANSFER AND "KNOWING WITH"

A PFL view of transfer fits nicely with Broudy's (1977) arguments about different types of knowing. Broudy argues that we must go beyond the "knowing that" (replicative knowledge) and the "knowing how" (applicative knowledge) that jointly constitute the characteristic focus of DA theories. People also "know with" their previously acquired concepts and experiences. "Knowing with" refers to the fact that the educated person "thinks, perceives and judges with everything that he has studied in school, even though he cannot recall these learnings on demand'' (p. 12). By ''knowing with'' our cumulative set of knowledge and experiences, we perceive, interpret, and judge situations based on our past experiences. ''Knowing with'' is compatible with Plato's analogy between knowledge and the sun; learning illuminates a situation without reproducing that situation.

Broudy argues that ''knowing with'' takes place through several different mechanisms. One is ''associative,'' which includes an activation of nonlogical relationships based on contiguity, resemblance, frequency, and other features discussed by associationist theorists. A second mechanism involves an interpretive function that affects how people categorize, classify, predict, and infer. Broudy argues that this interpretative function of ''knowing with'' is different from either a replicative or applicative use of knowledge:

> Interpretation, although essential to application, does not by itself yield any technology which can cause change. And although the interpretation of the situation invariably involves some use of a previous experience, it cannot be reduced to a simple replication of that experience. (p. 11)

Broudy emphasizes that much of the knowledge that supports ''knowing with'' is tacit and may be unavailable for recall except in its most skeletal form.

> The concept of bacterial 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)

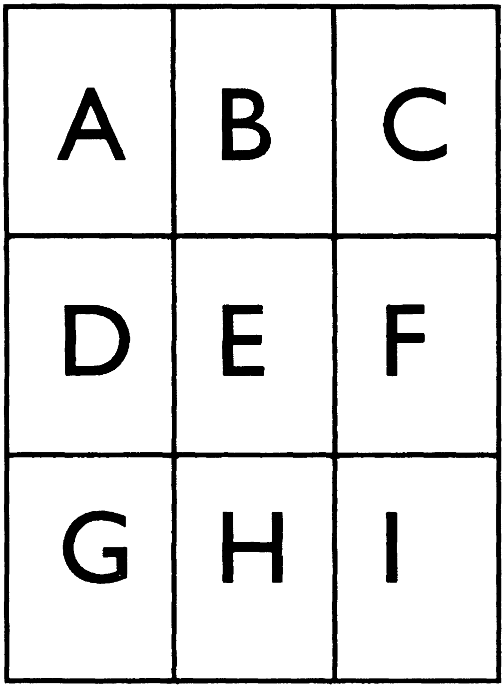
The absence of an idea of bacterial infection should have a strong effect on the nature of the hypotheses that people entertain in order to explain various illnesses, and hence it would affect their abilities to learn more about causes of illness through further research and study. This is similar to the findings from the eagle study discussed earlier, which showed that the college students, but not the fifth graders, began with ideas such as ''interdependence'' that influenced their learning goals for researching eagle recovery plans.

Perceptual Learning and "Knowing With"

Research on perceptual learning provides a good illustration of what it means to ''know with'' our experiences (e.g., Garner, 1974; Gibson & Gibson, 1955). Perceptual learning theorists point toward the importance of contrasting cases, such as glasses of wine side by side, as guides to noticing and differentiation. One is unlikely to be able to remember each of the contrasting cases, and experience with a set of cases will not necessarily allow one to induce principles that guide unaided problem solving. Nevertheless, experiences with contrasting cases can affect what one notices about subsequent events and how one interprets them, and this in turn can affect the formulation of new hypotheses and learning goals.

Garner (1974) provides a powerful illustration of the role of contrasting cases in noticing. He asks readers to look at a stimulus such as Figure 2 (we have

FIGURE 2
How Would You Describe This Figure?



adapted his demonstration to new figures) and then asks "How would you describe the figure?" Most people describe it as a grid with letters. Some may describe it as a set of lines.

The demonstration continues by considering the same figure (we label it the "standard" figure) in the context illustrated in Figure 3. This time the standard is in the context of another figure. Now features such as the size, shape, and symmetry of the grid and its rectangles become relevant. When people see the standard in isolation, they generally fail to mention anything about the size, shape, or symmetry of the grid.

We can continue the demonstration by considering the standard in a new context as in Figure 4. Now features such as font, number of grid entries, and "indexing" scheme become relevant.

Garner notes that one could continue to make contrasts indefinitely so that additional features become salient—features such as the thickness of the lines, the fact that the lines are solid rather than broken, and the color of the ink. Garner's conclusion from his demonstration is that a single stimulus is defined in the context of a "field" of alternatives. In Broudy's (1977) terms, this field

FIGURE 3
The Standard Figure in the Context of a Second Figure

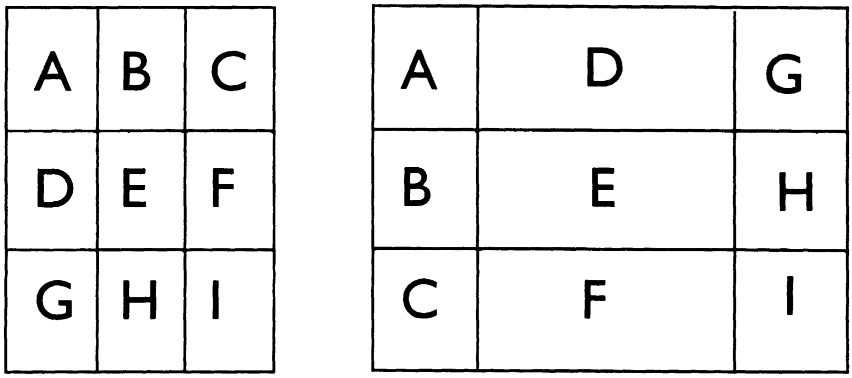
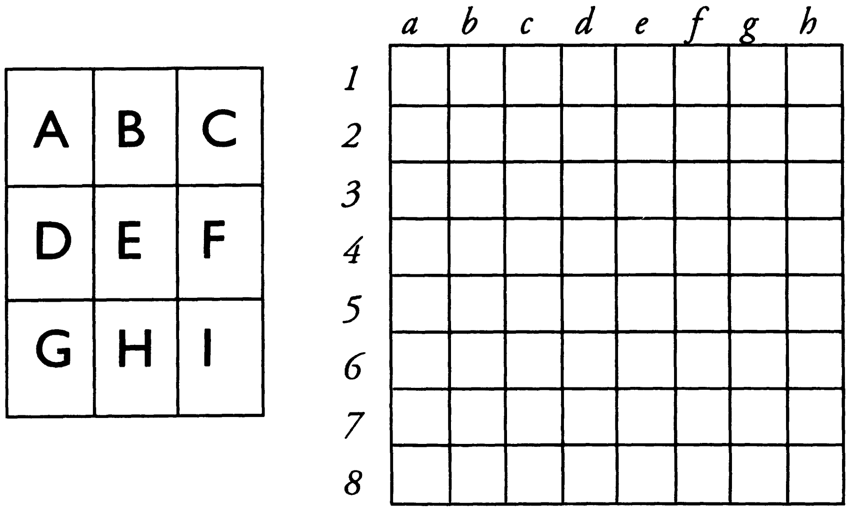


FIGURE 4
Putting the Standard in Different Contexts Reveals Different Features

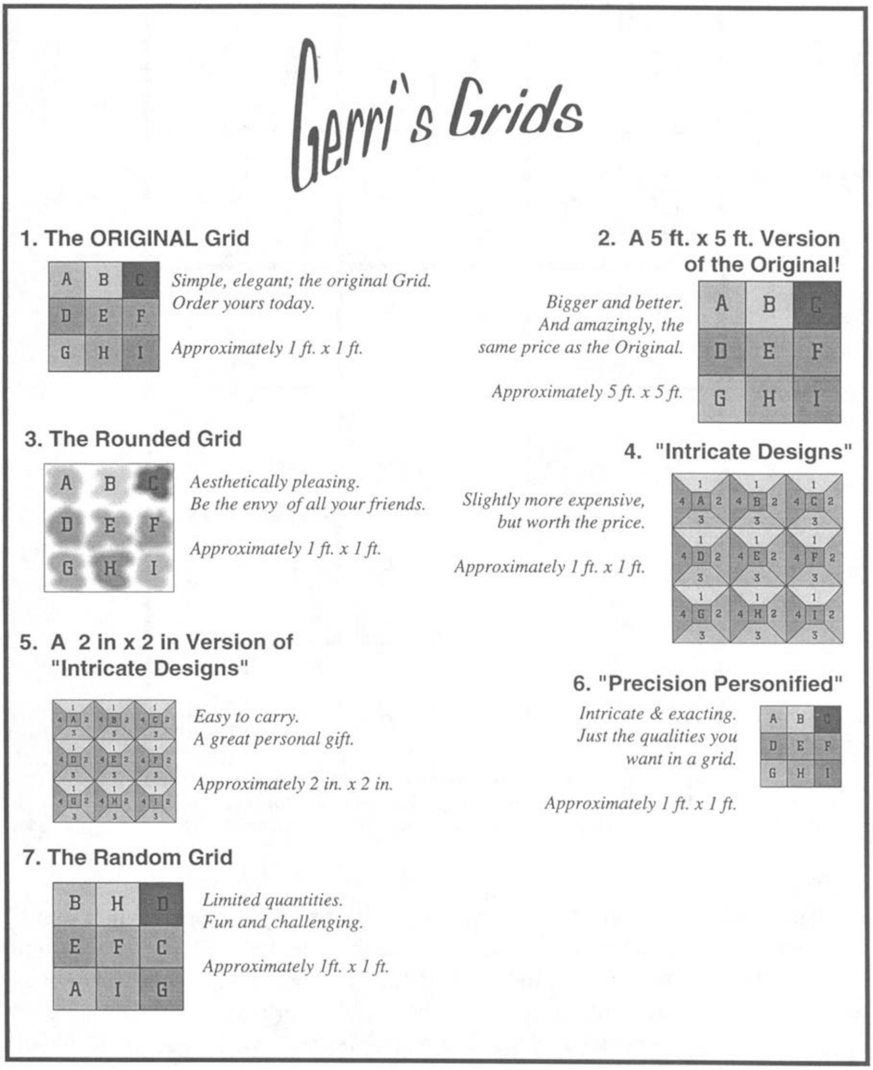


becomes something that we "know with"; it affects what we notice about subsequent events.

The field that people "know with" is not limited to perceptual alternatives. Changes in our ability to "know with" are also affected by the interpretations that we "know" the cases with in the first place. As an illustration, consider the set of grids shown in Figure 5. Each differs from the others, but it is difficult to know which features are most important.

What can be learned from Figure 5 is affected by additional interpretive knowledge that helps people develop learning questions. In the present case, for

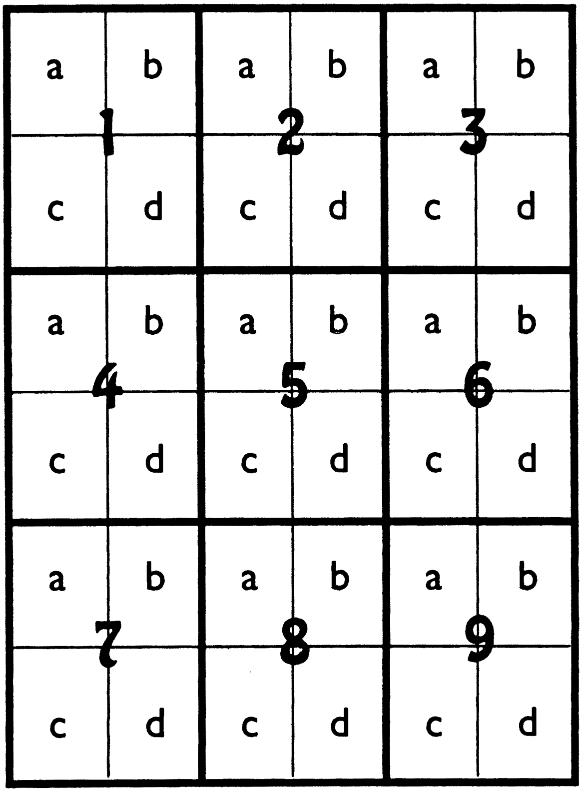
FIGURE 5
Which Grid Would You Choose and Why?



example, assume that the grids represent possible designs for the backs of T-shirts used to facilitate backscratching (Bransford et al., 1999). Given this information, it becomes possible to think about which features would be useful and which would not: Is the grid shaped correctly? Are the squares the right size? Does the design have an easy indexing scheme so that people can remember where to tell other people to scratch their shirts?

By comparing the grids in the context of a meaningful framework, people might improve in their ability to remember the individual cases. But even after

FIGURE 6
"Knowing With" Prior Experience



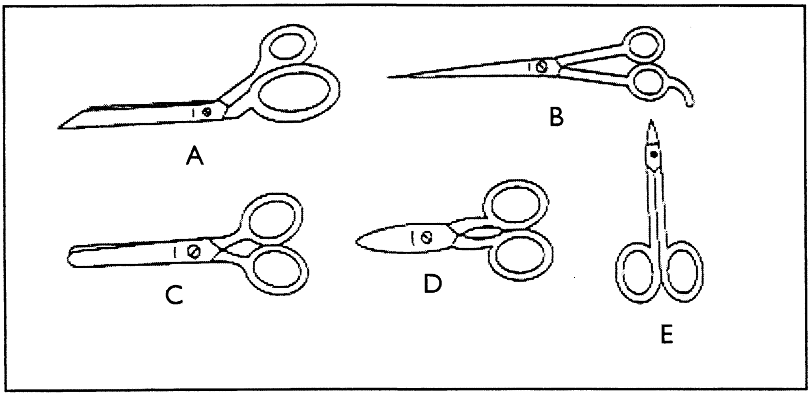
Note. After studying the previous backscratcher grids, people can evaluate the new features of this backscratcher grid even though the features are not "common elements" from the previous grids.

these individual cases are most likely forgotten, people can still "know with" their learning experiences, and this will affect subsequent processing. The learning experiences "set the stage" for further noticing, and their effects cannot be reduced to the mere replication of a particular experience per se (Bransford, Franks, Vye, & Sherwood, 1971). For example, they will affect how people interpret and think about the "transfer" backscratcher grid illustrated in Figure 6. Even though there are elements in this grid that are different from the original grids, and even though people's memories for the original grids may be poor, they can notice these elements and formulate goals for determining whether or not they are good features.

deGroot's (1965) conclusions from his classic studies of chess masters provide another example that is consistent with the concept of "knowing with":

We know that increasing experience and knowledge in a specific field (chess, for instance) has the effect that things (properties, etc.) which, at earlier stages, had to be abstracted, or even inferred are

FIGURE 7
Differentiated Knowledge Helps Experts Appreciate Properties That Novices Often Miss



Note. Adapted from "A Sketch of a Cognitive Approach to Comprehension," by J. D. Bransford and N. S. McCarrell, in *Cognition and the Symbolic Processes*, edited by W. Weimer and D. S. Palermo, 1974, Hillsdale, NJ: Lawrence Erlbaum Associates, Inc. Copyright 1974 by Lawrence Erlbaum Associates, Inc.

apt to be immediately perceived at later stages. To a rather large extent, abstraction is replaced by perception, but we do not know much about how this works, nor where the borderline lies. As an effect of this replacement, a so-called "given" problem situation is not really given since it is seen differently by an expert than it is perceived by an inexperienced person. (pp. 33–34)

How Contrasting Cases Set the Stage for Future Learning

A study conducted by the present authors shows how experiences with contrasting cases set the stage for learning new information (Schwartz & Bransford, 1998). The primary motivation for the study arose from the observation that novices in courses often miss important ideas because their knowledge is not as well differentiated as that of the experts (e.g., in a textbook) who explain various concepts. Imagine, for example, attempting to understand the statement "The dressmaker used the scissors to cut the cloth for the dress." This statement is probably easily understood by most people; they can imagine a person using a pair of scissors to cut some cloth. However, what is their concept of the dressmaker's scissors? A scissors expert will have a much more differentiated concept of scissors than most casual comprehenders (see Figure 7). As opposed to novices, for example, experts would know which features to look for when purchasing new scissors for a dressmaker.

As another example of the importance of well-differentiated knowledge structures, consider novices who attempt to comprehend the following: "The developmental psychologist showed first graders, fifth graders, and college students a set of 30 pictures and found that their memory for the pictures was equivalent."

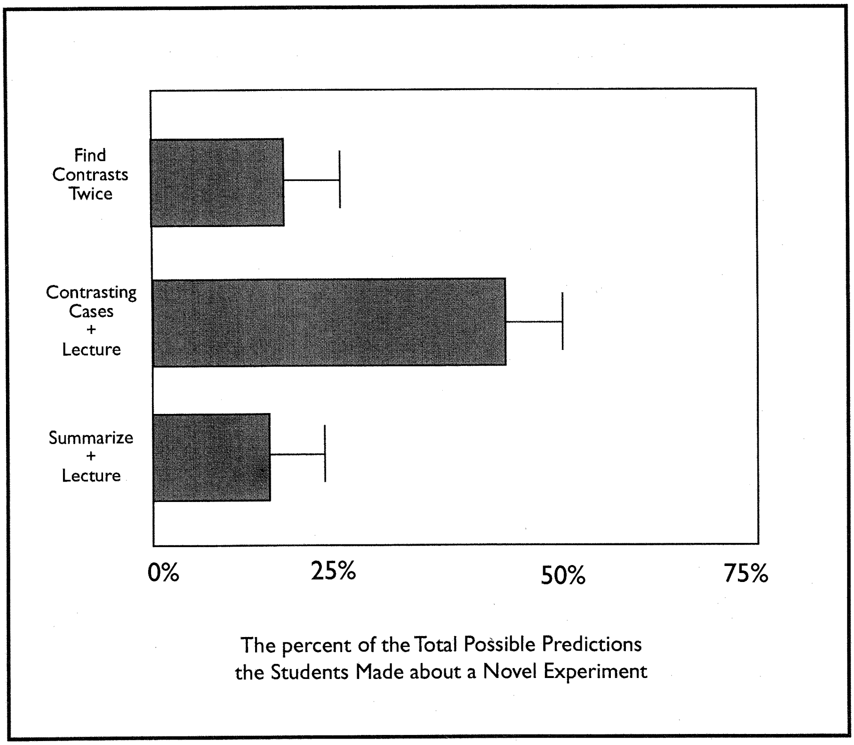
Novices can understand this statement at some level, but chances are that their understanding of "memory" will be relatively undifferentiated. In contrast, an expert will assume that this experiment involved recognition memory rather than free or cued recall, unless however, the 30 pictures were chosen to map very explicitly into a domain of organized knowledge in which the children were experts (e.g., see Chi, 1976; Lindberg, 1980). In short, the expert can construct a number of well-differentiated scenarios whereas the novice understands only superficially. (Schwartz & Bransford, 1998, p. 479)

The goal of our studies was to explore ways to help college students understand memory concepts (e.g., a schema). We knew from previous experiences that students often understood memory concepts only superficially and that attempts to simply explain all of the details of memory theories often did not remedy the situation. The hypothesis that drove our work was that students needed to develop a well-differentiated appreciation for the psychological phenomena explained by memory theories. We thought that an excellent way for them to do this was by analyzing simplified data sets from classic experiments and noting the patterns that emerged from the contrasting experimental conditions. In short, we used the "contrasting cases" methodology of the perceptual learning theorists (described earlier). We did not expect that the analysis of contrasting cases would, by itself, be useful. Students needed an explanation for the patterns of data they discovered, and it seemed unlikely that they could generate one without help from an expert. Therefore, our hypothesis was that the analysis of contrasting cases would better prepare the students for future learning from an expert. In Broudy's terms, the analysis of contrasting cases should provide a basis for "knowing with" when students hear or read the explanation of an expert.

Our experiments compared the effects of reading about memory experiments and theories versus actively analyzing sets of contrasting cases relevant to memory. Students in the contrasting cases condition worked with simplified data sets from original experiments. For example, they were given a sheet of paper that described the methods of an experiment in which subjects were asked to recall, with or without a delay, text passages that described typical events, and they received (simplified) data from groups of hypothetical subjects. Their task was to "discover" the important patterns in the data. Students in the other condition wrote a multipage summary of a textbook chapter. The chapter described the results of the experiments that the contrasting cases group analyzed, and it also provided the theoretical description of the results. We believed that opportunities to actively analyze contrasting cases of real data would help novice students develop differentiated knowledge of memory phenomena.

As noted earlier, our assumption was not that the analysis of contrasting data sets would, by itself, lead to deep understanding. Instead, we assumed that the use of contrasting cases would better prepare students to learn new information than would the activity of summarizing the text. As a means of examining this assumption, the new learning experience took the form of a lecture on memory theories and experiments. The lecture was heard by, and relevant to, both the "summary" group and the contrasting cases group. We also included a condition in which students analyzed the contrasting cases a second time, instead of hearing the lecture. This way, we could assess the degree to which the contrasting cases students actually learned from the lecture.

FIGURE 8
Contrasting Cases Prepared Students to Learn From a Lecture as Measured by a Subsequent SPS Transfer Test



Data strongly supported the assumption that contrasting cases better prepared students for future learning (see Figure 8). Students received a final prediction task that presented them with a new memory experiment and asked them to make predictions about the likely outcomes. Students in the "summarize plus lecture" group did not do nearly as well as students in the "contrasting cases plus lecture" condition. Equally important, the students who received experiences with contrasting cases (the "find contrast twice" group) but never heard the clarifying lecture did very poorly on the prediction task. The act of analyzing the cases prepared the students to learn from the lecture—it created a set of experiences that enriched subsequent learning. But the opportunity for further learning was needed. For those students who had not received an opportunity to hear the expert's lecture, the advantages of the contrasting case activities were not revealed.

NEW PERSPECTIVES ON QUALITY OF LEARNING

The most important characteristic of a PFL approach to transfer is not that it makes us feel better as educators because evidence for transfer is now more visible. Instead, the PFL approach is important because it provides a framework for evaluating the quality of particular kinds of learning experiences. A particular learning experience can appear "good" or "poor" depending on the task one is eventually asked to perform (Bransford, Franks, Morris, & Stein, 1979; Morris, Bransford, & Franks, 1977). The PFL perspective focuses on "extended learning" rather than on one-shot task performances. In doing so, it helps reveal the importance of activities and experiences whose benefits are hard to measure from an SPS perspective.

The preceding study that taught students about memory concepts provides a good example of the value of the PFL perspective (Schwartz & Bransford, 1998). Opportunities for students to examine contrasting cases of data did not by themselves affect the final transfer (prediction) task, which was an SPS assessment. Instead, these pattern-finding activities set the stage for subsequent learning from a lecture. Without this subsequent opportunity to learn, the value of analyzing contrasting cases would have been overlooked. There appear to be additional situations in which a PFL perspective can show the importance of learning activities whose strengths are not revealed in many kinds of testing contexts. Examples are discussed subsequently.

Perspectives on "Efficiency" and Errors

The PFL perspective draws attention to differences between short-term and long-term efficiency. Studies of word processing conducted by Sander and Richard (1997) represent a case in point. They found that attempts to help students understand the conceptual organization of a word-processing program led to accelerated abilities to learn new programs. However, it usually takes more time to introduce students to conceptual ideas than to have them simply focus on a particular set of skills or solution procedures. If the assessment task is how well people perform on the task they are taught, the conceptual method seems to be second best because it is not as efficient. But when assessment focuses on instructional procedures designed to prepare people for future learning, the perceived quality of the two methods reverses. Spiro and colleagues (1987) have argued that optimal learning experiences can be quite different depending on the characteristics of the knowledge domain the students are likely to encounter in the future. In today's world, it is likely that the word-processing programs that people use will change over time; thus, it seems wise to prepare them for change.

The PFL perspective can also help clarify the advantages of additional teaching techniques that appear inefficient from other perspectives. For example, consider efforts to compare the benefits of (a) beginning lessons by first having students generate their own, perhaps incorrect, thoughts about phenomena and (b) simply telling students the correct answers. Examples might include attempts to have students begin an instructional sequence by first generating their own experiment to test a certain idea (Bransford et al., 1990) or creating their own formula for capturing the variance of statistical distributions (Schwartz & Moore, 1998). Since novices will often generate ideas that are incorrect, they must eventually be guided toward more fruitful ways of thinking. Why not "cut to the chase" and present the correct ideas right from the start?

The PFL perspective suggests a number of reasons for first having students generate their own ideas about phenomena. One of the most important is that it provides an opportunity for students to contrast their own thinking with that of others, including experts in an area. This sets the stage for appreciating the critical features of the new information that is presented to them—analogous to the perceptual examples from Garner (1974) discussed earlier. For example, students who first generated their own thoughts on how to design an experiment to test a particular idea expressed appreciation about the elegance of the experiments discussed in an article that was then assigned to them (Bransford et al., 1990). In contrast, students who were simply assigned the article did not have the advantage of experiencing how the article helped clarify their own thinking. As a result, they treated the article simply as a set of facts to be learned.

Schwartz and Moore (1998) illustrate a similar example in the domain of statistics. The idea is that students are better prepared to appreciate the formula for standard deviation if they are first given opportunities to differentiate the elements of variability that the formula has to account for. To help differentiate these elements, students are shown an initial pair of distributions, say {2, 4, 6, 8, 10} and {4, 5, 6, 7, 8}. The experimenters point out that the two sets have a similarity, and they ask the students to note that there is a single number for each set that helps determine this similarity: the average. This single number is easier to keep in mind and communicate than the total distribution.

The experimenters then ask students to come up with a method for determining a single number for each set that could capture what is different (i.e., the variability). After students invent their own methods (often a range formula), they receive a new pair of distributions, say {2, 4, 6, 8, 10} and {2, 2, 10, 10}, and determine whether their formula works for this set as well. If it does not, they should fix it. This continues for several cycles in which students generate a formula and then try to apply it to new distributions that highlight new quantitative properties (e.g., dispersion or sample size). At the end of these exercises, students may be shown the variability formula used by experts. The question of interest is, How do these exploratory activities prepare students to understand the variance formula in ways that go beyond teaching the formula from the start?

Initial results from the studies (Moore & Schwartz, 1998) suggest that even though the students generated faulty formulas, these experiences helped the students become aware of the quantitative properties of distributions that a formula should take into account. This set the stage for noticing critical features of experts' formulas, for example, that they yield a smaller number for smaller variances (many of the students' self-generated formulas had done the opposite), that they elegantly solve the problem of set size, and so forth. As a consequence, students in the "generate first" group were much better able to appreciate the strengths and weaknesses of different nonstandard formulas for capturing variance (e.g., a formula that summed the deviations from the median instead of the mean). In contrast, students who had been directly taught the standard formula (with no previous attempts to generate their own thoughts) simply declared that the non-standard formulas were "wrong." They were not as prepared as the other students to learn about the expert formula. In Broudy's terms, they had a less well-differentiated "field" for "knowing with."

Perspectives on Negative Transfer and "Letting Go"

The preceding instructional procedures can also help accomplish another goal, namely, to let people experience how the seemingly "intuitive" or "obvious" ideas that they initially generate can appear suspect when subjected to closer scrutiny. This is important because adapting to new situations (transfer) often involves "letting go" of previously held ideas and behaviors. This is very different from assuming that transfer represents "the degree to which a behavior will be repeated in a new situation" (Detterman, 1993, p. 4). In many cases, repeating an old behavior in a new setting produces what has been labeled "negative transfer." Luchins's (1942) classic studies of filling water jars illustrate this point nicely. When given a transfer task, participants in these experiments repeated a complex set of water-pouring strategies despite the fact that the task permitted a simple, efficient response. Land, inventor of the Polaroid Land camera, coined a colorful definition of "insight" that highlights the importance of "letting go" of previous assumptions and strategies rather than simply repeating them. He defined insight as "the sudden cessation of stupidity" (Land, 1982). Toulmin (1972) also emphasized the importance of well-reasoned changes in one's beliefs and assumptions:

> A person demonstrates his (or her) rationality, not by a commitment to a fixed set, stereotyped procedures, or immutable concepts, but by the manner in which and the occasions on which, he (she) changes those ideas and procedures. (p. v)

Educational environments that are designed from a PFL perspective emphasize the importance of encouraging attitudes and habits of mind that prepare people to resist making old responses by simply assimilating new information to their existing concepts or schemas. Instead, effective learners learn to look critically at their current knowledge and beliefs (e.g., Novick, 1988).

Our colleagues Kay Burgess and Xiaodong Lin have documented the effects of an overreliance on assimilation. They created catalogs of items that one might purchase for an eagle recovery plan. Some of the items were bogus and would not work. Fifth and sixth graders were given the catalogs along with resources they could use to help make their catalog selections. Most were overconfident of their competence for this task. They simply used their everyday intuitions as human beings and made decisions (which tended to be wrong) without consulting any resources. For example, they chose the option of hand-raising baby eagles because the babies would "feel like orphans" if they put them in an isolated incubator. (The problem with hand-raising eagles is that the babies would imprint on humans.) In contrast, a science expert who had no knowledge of eagle recovery took a totally different approach. She knew that she needed more information and used the contrasting catalog items to formulate learning goals that guided her search through the resources available for the study. She exhibited adaptive expertise (Hatano & Inagaki, 1986).

Wineburg (1998) provides an additional example of the importance of overcoming the tendency to simply assimilate. He studied a historian who was asked to analyze a set of history documents that focused on a topic outside his area of specialization. At first, the historian resolved puzzling contradictions in the documents by using his existing knowledge of present-day culture. Eventually, he came to the conclusion that he did not have enough historical knowledge about the situation to make an informed judgment, so he devised learning goals and carried them out. After opportunities to learn, the historian did as well at analyzing the history documents as an expert who specialized in that area. In contrast, college students presented with the same documents tended to use their intuitive everyday knowledge and generated erroneous conclusions (Wineburg & Fournier, 1994). They failed to question their existing assumptions and, ultimately, failed to take advantage of new opportunities to learn.

People's mental models of what it means to be successful appear to affect their abilities to "let go" of previous beliefs and become effective learners. Elsewhere (CTGV, 1997), we have discussed the impediments to learning that are caused by people who have a (usually tacit) mental model that being "accomplished" or "an expert" means that they should know all of the answers. A healthy alternative is one that celebrates being an "accomplished novice" who is proud of his or her accomplishments but realizes that he or she is still a novice with respect to most that is knowable and, hence, actively seeks new learning opportunities. The effects of finished—expert versus accomplished—novice models are difficult to show from an SPS perspective. However, they should be revealed from a PFL perspective when people, for example, are given opportunities to collaborate and they naturally demonstrate their (un)willingness to listen and learn.

The multiply embedded social settings within which people's lives unfold have a powerful effect on the degree to which they are supported in letting go of older ideas and practices and attempting new ones. Our colleague Xiaodong Lin (1999) studied a Hong Kong mathematics teacher who agreed to try a new (for her) instructional approach in her mathematics classroom: She structured a week's worth of lessons around a Jasper problem-solving adventure (see CTGV, 1997) that had been translated into Chinese (Lin et al., 1995). The changes the teacher had to make in her teaching practices were extensive, but she and her students ultimately were successful in creating a learning experience that was satisfying to all of them.

The teacher's reflections on her experiences demonstrate the powerful impact of the social contexts in which she was embedded. First, she noted that her teaching performance was evaluated by both students and their parents, so she had to be very mindful of their opinions. Second, she noted that the principal and the parents were very positive about innovations that had the potential to prepare students to better adapt to the fast-changing world of Hong Kong. This support for innovative risk taking was crucial in convincing the teacher to accept the challenge of implementing Jasper in her classroom. The teacher also noted that her school was not a "top tier" school, and thus there were constant attempts to find an edge by taking risks and trying new programs. This made the invitation to experiment with Jasper a positive opportunity rather than too much of a risk. Despite all of this support, the teacher still proceeded very cautiously and reflectively; she assembled daily written feedback from the children and studied it prior to the subsequent day's activities. By systematically noting students' current understandings and questions, she was able to adjust her teaching in ways that ultimately led to success. Overall, the teacher had acquired a set of knowledge, beliefs, and strategies that allowed her to adapt to new technologies.

Perspectives on the Active Nature of Transfer

The act of critically examining one's current beliefs and strategies is related to another important feature of the PFL perspective, namely, its focus on the active nature of transfer. The learning environments in which people must eventually operate are not necessarily "given" (Pea, 1987). As deGroot (1965) observed with respect to chess and as the Garner examples demonstrate, people's perception of the givens of a situation depends on what they have at their disposal to know with. Thus, the individual's knowledge actively constitutes the perceivable situation.

People can also change the situation itself. They can modify their environments by changing them physically, by seeking resources (including other people), by marshaling support for new ideas, and so forth. Rather than simply viewing transfer as the mapping of old understandings and practices onto a given situation, the PFL perspective emphasizes that people can actively change the given situation into something that is more compatible with their current state and goals.

An interesting example of this comes from research in robotics (Hammond, Fasciano, Fu, & Converse, 1996). Robots are being taught to stabilize their environments to simplify their tasks. For example, kitchen robots make sure that the refrigerator is full, and they put the briefcase next to the door so that it will not be forgotten. More generally, people actively adapt their environments to suit their needs. For example, they will modify the positions of utensils and dry goods when they go to a new kitchen. This new kitchen does not have to be exactly like their old one (e.g., the kitchen might have a different number of drawers). People accommodate their old schemes to the new kitchen, and they adapt the kitchen to their old schemes and "personal" strengths. Actively controlling the environment seems especially important with regard to future learning, yet it is something that is typically outside the realm of SPS tests and DA models of transfer.

An important way in which learners interact with their environments is by creating situations that allow them to "bump up against the world" in order to test their thinking. If things do not work, effective learners revise. The importance of these kinds of "test your mettle" opportunities is illustrated by research on our Jasper problem-solving series (CTGV, 1997). In some of our more recent work, we have begun to ask students to create "smart tools" that allow them to solve a wide variety of problems (e.g., graphs and tables; Bransford et al., 1999). In this context, we have created "embedded teaching scenes" (see CTGV, 1997) and additional materials that provide models for smart tools that students can adapt in a "just-in-time" fashion. If the effectiveness of this instructional approach is evaluated in a typical one-shot SPS paradigm, it looks weak and problematic.

For example, in one study with middle school students, more than half of the students chose the wrong smart tools, and most used the embedded teaching models inappropriately. However, the students' performances changed quite dramatically once they received an opportunity to test the mettle of their tools and revise their thinking. After only one such experience, the percentage of correct choices of smart tools (along with the ability to explain choices) jumped from less than 40% to more than 80%. Opportunities to receive feedback and improve one's work have been shown to help students increase their appreciation of the revision process (e.g., Schwartz, Lin, Brophy, & Bransford, 1999). Additional research indicates that experiences such as these strongly increase the likelihood that students will spontaneously invent their own tools to control novel problems in their environment (Schwartz, 1993).

An especially important aspect of active transfer involves people's willingness to seek others' ideas and perspectives. Helping people seek multiple viewpoints about issues may be one of the most important ways to prepare them for future learning. Physicist David Boehm points out the value, and emotional turmoil, involved in seeking others' opinions; his description refers to a scientist (in this case, a male scientist) being confronted by conflicting opinions:

> His first reaction is often of violent disturbance, as views that are very dear are questioned or thrown to the ground. Nevertheless, if he will "stay with it" rather than escape into anger and unjustified rejection of contrary ideas, he will discover that this disturbance is very beneficial. For now he becomes aware of the assumptive character of a great many previously unquestioned features of his own thinking. This does not mean that he will reject these assumptions in favor of those of other people. Rather, what is needed is the conscious criticism of one's own metaphysics, leading to changes where appropriate and ultimately, to the continual creation of new and different kinds.

The need for people to actively seek others' perspectives is also central to Lagemann's (1997) insightful discussion of the history of education research during the past century. She shows how this history can be viewed as a fight among different professional groups (e.g., measurement experts, learning theorists, school administrators, teachers' unions) for jurisdiction over the domain of education. She directly links possibilities for future learning to the need for collaboration across professions:

> What all this suggests, I think, is that professionalization has been a barrier to the effective linking of knowledge and action in education. . . . Possibilities for the future will depend on understanding

and surmounting the constraints of professionalization in order to develop more truly equal, genuinely respectful, and effectively collaborative relationships among the groups most directly involved in the study and practice of education.... If new, more collegial patterns of collaboration can be nourished and sustained on even a small scale and the difficult political problems of this enterprise better understood and more widely and openly discussed, it may be possible to encourage the more democratic, cross-profession, cross-discipline, cross-gender social relationships that would seem to be an indispensable precondition to effective knowledge-based reform in education. Were that to happen, there would be much to be gained. (p. 15)

Overall, one of the important lessons of the PFL perspective is that it moves "affective" and social concepts such as "tolerance for ambiguity" (Kuhn, 1962), courage spans (Wertime, 1979), persistence in the face of difficulty (Dweck, 1989), willingness to learn from others, and sensitivity to the expectations of others from the periphery toward the center of cognitive theories of learning. These factors can have a major impact on people's dispositions to learn throughout their lives. The PFL perspective emphasizes the importance of understanding the kinds of experiences that prepare people to question their own assumptions and actively seek others' opinions on issues.

Research in the area of "metacognition"—especially research on reflection and comprehension monitoring—provides information that is relevant to this question (e.g., see Brown, 1978; Flavell, 1976; Hacker et al., 1998; Pressley & Afflerbach, 1995; White & Frederickson, 1998). People who actively monitor their current levels of understanding are more likely to take active steps to improve their learning. Nevertheless, monitoring is not a "knowledge-free" skill; people whose knowledge is not well differentiated can think they understand yet fail to understand at a sufficiently deep level (see Schwartz & Bransford, 1998; Vye et al., 1989). Helping students develop well-differentiated knowledge—and helping them understand its role in self-assessment—is an important part of preparing them to learn throughout their lives.

We believe that people's preparation for future learning can be further enriched through an active examination of issues that are more frequently raised in the humanities than in the natural sciences. What are examples of "effective learners" who can serve as models for lifelong inquiry? How do we evaluate "inquiry" per se rather than evaluate only the results of one's inquiry (i.e., whether one's findings seem true or false with respect to current theory)? Issues such as these are discussed in the next section.

Perspectives on "Lived Experiences" and the Humanities

The PFL perspective may eventually help us better appreciate the value of a number of "humanistic" activities, including (a) "lived experiences" that introduce people to alternative perspectives and cultural assumptions (e.g., living in another country or participating in "alternative spring breaks" to work in Appalachia) and (b) studying the arts and humanities in order to better understand the nature of the human condition and one's place within it. From the perspective of the SPS methodology and DA theory, it is difficult to show the value of these experiences because they do not readily affect immediate problem solving. From a PFL perspective, it may become easier to conceptualize and assess their value. This, in turn, can help us better understand how to structure experiences so that people receive maximum benefits.

Consider "lived experiences" such as spending time in a different country. These experiences can function as "contrasting cases" (see our earlier discussion of Garner and others) that help people notice features of their own culture that previously were unnoticed. The experiences can prepare people to be more appreciative of others' ideas and values as they encounter them throughout their lifetime and, eventually, to actively seek others' opinions about important issues and hence accelerate their abilities to learn. However, just as experiences with a set of contrasting data cases required a summarizing lecture to help students develop a conceptual framework that eventually led to strong transfer (see our earlier discussion of the Schwartz and Bransford study), it seems highly probable that people need help thinking about their experiences and organizing them into some coherent view of the world.

This same point seems relevant to other lived experiences such as learning to play a musical instrument, learning to perform on stage, and learning to participate in organized sports activities. Some music, drama, and athletic teachers (coaches) appear to help students learn about themselves as they struggle to perform in these arenas. Other teachers seem to focus solely on the performance and provide minimal suggestions for helping students think through important issues such as their commitment to excellence; their need to be in the limelight rather than a team player; their respect for others who are not equally musical, dramatic, or athletic; their (often tacit) fears and strategies that may be hampering their progress (e.g., in sports, some people fall into the trap of "playing not to lose" rather than "playing to win"). The PFL perspective suggests that, when properly mediated, lived experiences can provide powerful resources for "knowing with" (Broudy, 1977). It also reminds us that we need a much better understanding of the kinds of "mediated reflections" that best prepare people for learning throughout life.

Many believe that lived experiences can be enriched by a study of the arts and the humanities. Broudy, for example, argues that "the study of poetry enriches the imagic store in ways that everyday experiences may not" (1977, p. 11). He contends that experiences of viewing art or reading poetry have a strong impact on "knowing with" when they are subjected to serious study and analysis. In part, this is because study of the arts and humanities provides invaluable opportunities to contrast surrogate experiences with one's own. And in part, this is because the arts and humanities offer frameworks for interpreting experiences and helping people develop a more coherent world view.

A particularly important challenge from the perspective of PFL is to explore ways to help people balance their respect for knowledge gained from areas such as science, history and literature, religion, and personal experiences. Our bet is that most people (ourselves included) do not have a well-differentiated conception of what it means "to know" when thinking about different areas of their lives. According to Broudy (1977):

> The evidence for the assertions "The sun is 93 million miles from earth" and "I know my Redeemer livith" are not of the same order. The self-evidence of mathematical tautologies is not the same as that entailed by "Beauty is its own excuse." Humanistic truth of knowledge involves something other than logical or scientific validity. Perhaps it is authenticity. Authenticity is the property of being genuine, nonfake, as really issuing from the source that claims to originate it. (p. 5)

Helping people develop an appreciation of, and commitment to, an authentic pursuit of new knowledge seems particularly important for preparing them for future learning. Such pursuits usually involve a combination of humanistic and scientific/mathematical approaches and cannot be reduced to one or the other alone. Nobel Laureate Sir Peter Medawar captures this point in his discussion of the scientific method:

> Like other exploratory processes, [the scientific method] can be resolved into a dialogue between fact and fancy, the actual and the possible; between what could be true and what is in fact the case. The purpose of scientific enquiry is not to compile an inventory of factual information, nor to build up a totalitarian world picture of Natural Laws in which every event that is not compulsory is forbidden. We should think of it rather as a logically particular structure of justifiable beliefs about a Possible World—a story which we invent and criticize and modify as we go along, so that it ends by being, as nearly as we can make it, a story about real life. (1982)

Broudy's emphasis on "authenticity" as a humanistic truth provides a potentially powerful focus for preparing people for future learning. The genuineness of people's inquiry is relevant in all areas: science, mathematics, history, literature, and so on. It represents a characteristic of individuals and groups that can be differentiated from less genuine endeavors such as efforts to propagate a set of ideas without regard for evidence, efforts to simply "get something finished" without worrying about quality, and efforts to take credit for work that is not one's own.

People's appreciation of authenticity in inquiry is nicely illustrated in a cross-cultural study conducted by Xiaodong Lin and her colleagues (Lin et al., 1995). Middle school students in Nashville, Tennessee, communicated electronically with students in Hong Kong about different aspects of Chinese history. The American students constructed "day in the life" scenarios that described the lives of fictitious individuals who lived during earlier times in China (e.g., during the Tzeng dynasty). The Hong Kong students (who were one grade more advanced than the Nashville students) read these stories and provided feedback about the quality of the work. The feedback often seemed harsh to the Nashville students until Lin and her colleagues implemented a simple but powerful procedure. They asked the Nashville students to accompany their work with a self-assessment of how well they had achieved particular goals such as creating stories that were interesting and accurate with respect to Chinese culture. The Hong Kong students reacted very positively to these self-assessments. For example, one group of

Hong Kong students wrote a detailed critique of a story generated by Nashville sixth graders and ended their comments with the following:

> Your story was not very deep and complex. You seem to like to buy things because all of your story focused on markets of the time. However, from your self-assessment, we felt that you are willing to look into yourself for improvement and you are quite thorough about it. Overall, you guys seem to be good people.

This example illustrates the importance of different criteria for evaluating quality. One set of criteria involved evaluations of the Nashville students' stories from the perspective of story complexity (including interest) and historical accuracy. A second set of criteria focused on perceived intentions and aspirations of the authors. Even when the historical stories were weak and historical accuracy was questionable, the Hong Kong students respected the willingness of the Nashville students to reflect on their own work, criticize it, and welcome feedback. There was a strong (and we believe accurate) perception that the Nashville students were engaged in authentic inquiry rather than simply attempting to complete a task and move on. The self-assessment resulted in feedback that included many more positive comments mixed with the criticisms (see the preceding example). U.S. students in the self-assessment condition felt more of a bond with the Hong Kong students and were more likely to continue to want to work with them.

Issues related to the authenticity of inquiry may lie at the heart of debates about grading for "effort" as well as "achievement." Acknowledging the authenticity of students' inquiry seems very valuable in terms of preparing them for future learning. Redefining effort as authenticity may be useful for helping teachers rethink such acknowledgments. A serious study of the humanities—by both teachers and students—should help develop a more differentiated understanding of what authenticity might mean.

At a more general level, the idea of combining the study of the humanities with the study of mathematics and the sciences is, of course, the rationale for a liberal arts education. Ideally, people can be helped to develop a coherent, well-differentiated framework for "knowing with" that is relevant to life in general rather than specific to only one particular discipline or field.

The PFL perspective reminds us that some ways of structuring liberal arts experiences will be more useful than others, For example, it is doubtful that students develop a coherent, well-differentiated perspective for "knowing with" simply by taking a set of courses in the humanities, science, and mathematics. First, many of these courses are disconnected from one another, and hence there is no common ground for comparison and contrast. The experience is similar to viewing Figures 2–6 without the common ground supplied by the idea that these are possible designs for backscratcher T-shirts. Without this "ground" or "field," many important distinctions are missed.

A second problem with many liberal arts programs is that the experiences in many of the courses appear to resemble the summarize plus lecture condition in the Schwartz and Bransford study—the students read and summarize a text and then hear an organizing lecture. They have no opportunity to deal with specific cases that set the stage for their future learning (Figure 8 shows the effects of this type of instruction). The ideas that students are exposed to in formal courses are often not grounded (anchored) in their experiences. Understanding how to improve this situation is a major challenge for educators. The PFL perspective serves as a reminder that these issues are worth exploring. It also suggests methodologies for studying the issues. This topic is discussed subsequently.

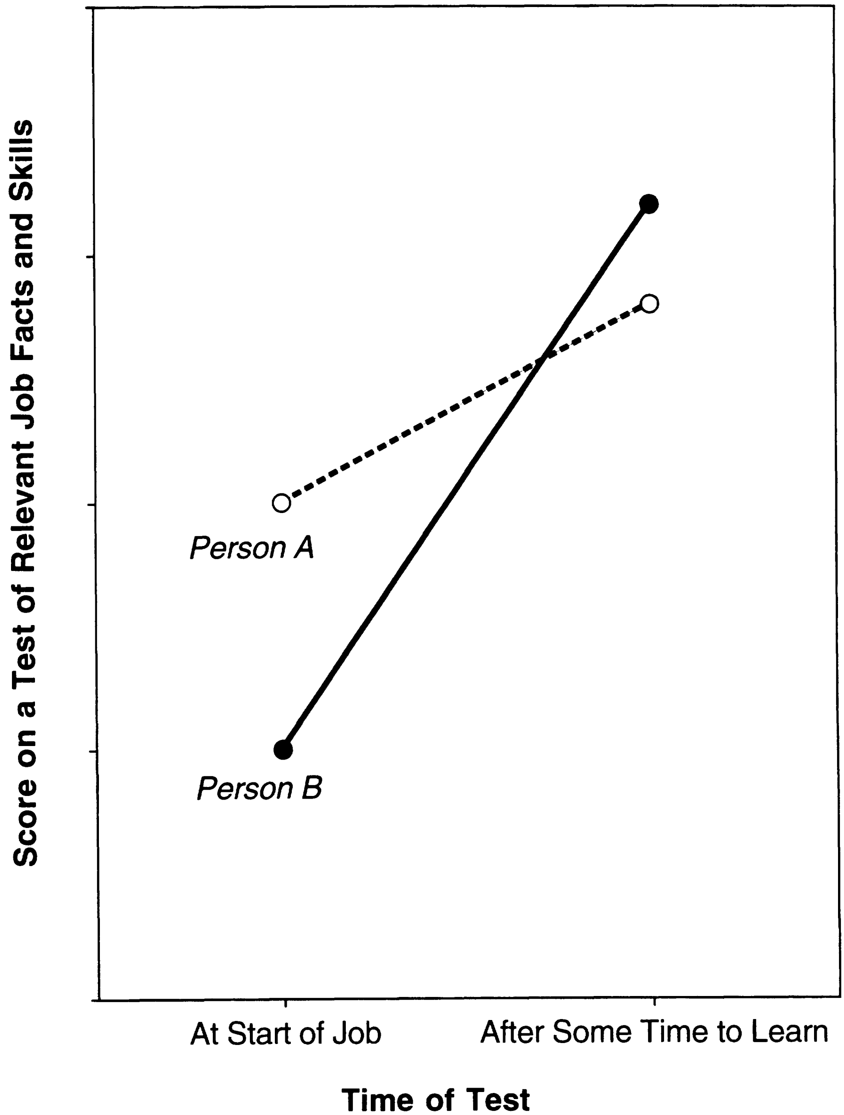
FROM STATIC TO DYNAMIC ASSESSMENTS

The PFL perspective suggests that assessments of people's abilities can be improved by moving from static, one-shot measures of "test taking" to environments that provide opportunities for new learning. What one currently knows and believes is clearly important for future learning. Yet, SPS tests of current knowledge are indirect measures of people's abilities to learn; they do not capture the learning process itself. For example, they do not directly capture the dispositions that influence people's learning; rather, they capture only the dispositions that influence test taking (e.g., Dweck, 1989; Holt, 1964; Ng & Bereiter, 1991). Moreover, there are possible dissociations between SPS and PFL assessments. Figure 9 illustrates this possibility. It shows two people, A and B, who begin a job. On SPS tests of facts and problems deemed relevant to the job, person A scores better than B, perhaps because A had some specific, job-relevant training. Over time, however, B turns out to be the most effective learner. Similar scenarios are possible in other settings; for example, the top 10% of nation A's students may look better than nation B's on SPS tests, yet it is possible that nation B's students are more broadly prepared for future learning. The PFL perspective does not make such a prediction; rather, it simply suggests that such questions need to be asked. The PFL perspective also suggests the possibility that a dynamic assessment of a person's ability to learn over a period of a month might better predict that person's success 4 years down the line at a job or in college than a one-shot SPS test at the beginning. This is a major challenge for future research.

We attempt to illustrate the potential importance of dynamic assessment by discussing a particular problem environment that we have been exploring. Participants are presented with a challenge that involves items such as those illustrated in Figure 10. They are asked to choose the one that gives them the most and the least for their money. We have given this challenge (and others like it) to a wide range of individuals, from middle school students to adults. Their reactions to the challenges tell us a lot.

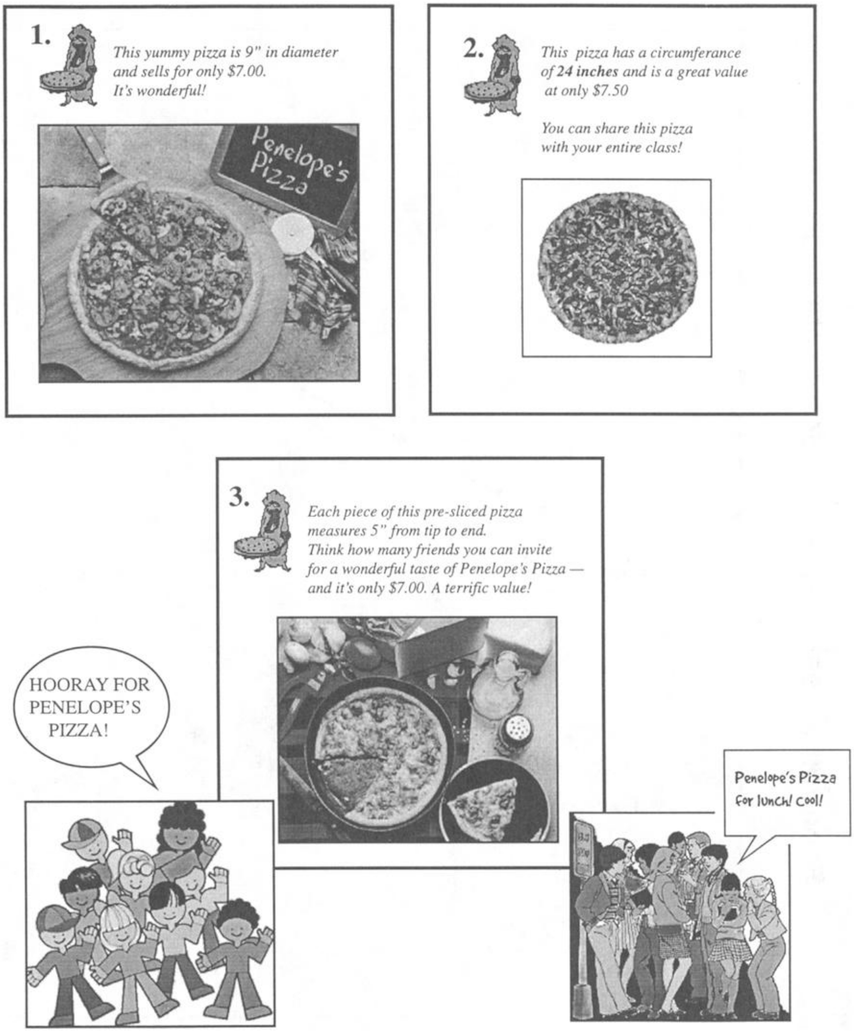
Consider first the middle school students. Most of them get the challenge wrong. They choose the items with the "biggest number" (for the best deal) and the "smallest number" (for the worst deal). Many of these students are quite confident about their answer and do not feel the need for further learning or discussion. High confidence without corresponding competence creates situations that are the furthest from being ideal.

FIGURE 9
Static Tests May Not Predict Who Will Perform Best When There Is an Opportunity to Learn More



Other participants who make the wrong choices are more aware that they do not know the answer. Some, especially many of the adults (who have not been in school for some time), feel that they simply need to be reminded of the definition of terms such as diameter and circumference; others request definitional help along with a reminder of relevant geometry formulas (e.g., C = pi D). Still

FIGURE 10
Which Pizzas Give the Most and Least for the Money?



other participants (especially many middle school students) are not confident about their answers but cannot define the kinds of help they need in order to proceed. For example, one group of students engaged in an intense discussion for more than 10 minutes before a group member asked "Would it help to know what diameter means?"

To provide an example of a dynamic approach to this problem, we have begun work with several colleagues (Jan Altman, Sean Brophy, Joan Davis, Nancy Vye, Linda Zech) on computer-based environments for dynamic assessment. This work draws heavily on the dynamic assessment literature (e.g., Bransford et al., 1987; Campione & Brown, 1987; Cole & Griffin, 1987; Feuerstein, 1979; Lidz, 1987; Vygotsky, 1978). The environment is designed to assess people's preparation for learning to solve particular classes of problems. By participating in these environments, people can also learn to self-assess their readiness to learn. Our prototype is organized around a set of geometry problems similar to "Penelope's Pizza Challenge" (see Figure 10). Participants first (a) answer the challenge, (b) indicate their confidence in their answer, and (c) indicate whether they want to go on to a different kind of problem or check out resources for how to solve the pizza problem. If participants answer correctly and confidently, they receive one additional analogous problem. If they repeat their confidence and competence, they can go on to more challenging problems to solve.

The most interesting data come from people who cannot initially solve the problem. If they are wrong but confident of their answer, these data are recorded. If they are wrong and not confident (which is a much healthier pattern), these data are also recorded. Participants are then given feedback about their initial answers, for example, feedback that emphasizes the dangers of confidence with little competence and feedback that helps people appreciate the value of "problem finding" (cf. Bransford & Stein, 1993)—of discovering the existence of a problem and taking steps to fix it.

After receiving feedback, participants are provided with opportunities to access different resources that might help their learning. They can choose to seek "minimal help" (e.g., a dictionary of definitions), "intermediate help" (e.g., a brief verbal lecture about relevant information), or several levels of "extended help" that provide opportunities to see dynamic visual events (rather than hear only lectures) and to explore relationships through the use of simulations. Participants access the type of help they need and decide for themselves when they are ready to solve an analog of the original challenge problem. Once again, the program assesses their competence and confidence and offers them additional opportunities to learn the relevant information and apply it to a series of analogous problems. Over time, participants should need less and less assistance in order to solve the challenge problems. If none of the types of help work for them, they are given opportunities to assess the learning opportunities and suggest ways that they might be improved.

Our fledgling dynamic assessment environments are just being developed. They are not yet as social as we want them to be, although users can interact with virtual experts who provide guidance. Ultimately, we believe that dynamic assessment environments will yield interesting information that will be valuable to both teachers and students. Teachers who focus solely on "teaching to the test" may find that their students have difficulty assessing their own knowledge and learning on their own. Similarly, the dynamic assessment environments should help students learn about themselves as learners. And, depending on the topic, they should begin to differentiate cases in which they need simple reminders from ones in which they need opportunities for in-depth exploration. In addition, the dynamic assessment environments help students see learning positively. Students are not simply "being tested"; instead, they are assessing the adequacy of different strategies for learning, and they are using these opportunities to control their learning environments.

SUMMARY

We have proposed a way to think about transfer that is simple yet has important implications for educational practice. In addition to the more typical approach, which views transfer as the direct application (DA) of knowledge and measures it in a context of sequestered problem solving (SPS), our proposal is to view transfer from the perspective of preparation for future learning (PFL). The idea of transfer as PFL is not unique to us; many other theorists have linked transfer to learning. Nevertheless, the educational implications of different views about transfer have not been as well differentiated in the literature as they might be. Our goal in this chapter has been to more explicitly contrast the SPS and DA view from the PFL approach and show how they diverge.

We have argued that the PFL perspective reveals evidence of transfer that is easy to miss when one adopts a DA theory and its accompanying SPS methodology. The latter focus on the degree to which people can apply their previous knowledge to solve new problems. Data often show how far people are from complete solutions and give the impression that transfer is rare. In contrast, the PFL perspective focuses on evidence for useful learning trajectories. Examples include the sophistication of the questions students ask about a topic and the assumptions that are revealed in their discussions (we demonstrated this in the context of recovery plans for bald eagles). More sophisticated questions and assumptions lead to learning activities that are more likely to help people acquire the relevant expertise.

We noted that the PFL perspective fits nicely with Broudy's emphasis on "knowing with." Typical assessments of learning and transfer involve what Broudy calls the "replicative" and the "applicative" (knowing that and knowing how, respectively). "Knowing with" is different from either of these; it provides a context or "field" that guides noticing and interpretation. Perceptual learning provides an excellent example of "knowing with." As the demonstration of the "transfer backscratcher grid" showed, noticing new features is not an act of simply finding common elements between the past and present. Through contrasting cases, one develops the ability to notice finer and finer distinctions. One becomes a connoisseur of the world.

An important implication of the PFL perspective is that it can show the value of a variety of learning activities whose impact is difficult to measure from an SPS perspective. For example, a study conducted by the present authors demonstrated that opportunities to actively compare sets of contrasting data patterns were extremely helpful to students, but their usefulness did not show up unless students were given the opportunity to learn new information. We argued that students were better prepared for this learning because they had acquired a more differentiated field for "knowing with."

We discussed additional instances in which the PFL perspective suggests the value of learning activities that might seem to be a waste of time from an SPS perspective. Examples included helping people learn a particular software package versus taking the extra time to prepare them to continually learn new packages and understanding the value (from the perspective of contrasting cases and knowledge differentiation) of first having students generate their own thoughts about a topic and then comparing them with the thoughts of others, including experts.

The PFL perspective also highlights the importance of dispositions that affect future learning. Future learning frequently requires "letting go" of previous ideas, beliefs, and assumptions. Effective learners resist "easy interpretations" by simply assimilating new information into their existing schemas; they critically evaluate new information and change their views (accommodate) when necessary. We presented two examples, one involving work with eagle catalogs (Burgess & Lin, 1998) and one involving interpretations of historical texts (Wineburg, 1998). In both cases, transfer involved conceptual change rather than the persistence of previous behaviors and beliefs.

We also argued that the PFL perspective highlights the importance of allowing people to actively interact with their environments—opportunities that are rarely present in SPS environments. When people have opportunities to "bump up against the world" and receive feedback, their learning can improve quite dramatically, and the value of their previous experiences can be revealed. To illustrate this point, we noted how the use of instructional approaches such as embedded teaching (analogous to worked out examples) in our Jasper adventures (CTGV, 1997) can result in an alarming number of errors in an SPS paradigm. However, after only a single opportunity to "test their mettle" and revise, students' performances improved dramatically.

An especially significant benefit of the PFL perspective is that it may help us understand how to maximize the value of a variety of experiences (e.g., studying the humanities; participating in art, music, and sports; living in a different culture) that seem important intuitively but are difficult to assess from a DA point of view.

We concluded our discussion by noting the implications of the PFL perspective for assessment. Most assessments follow the SPS format; in Broudy's terms, they emphasize the replicative and the applicative. Using the logic of "transfer appropriate processing" (e.g., Morris, Bransford, & Franks, 1977), we argued that the activities that prepare people for static tests may be different from those that best prepare them for future learning. In conjunction with a number of colleagues, we are constructing computer-based dynamic assessment environments to explore this idea.

We finish our chapter with the observation that the DA perspective and its accompanying SPS methodology have been, and will undoubtedly continue to be, very important in the cognitive literature. The SPS paradigm provides a methodology for empirically determining the psychological similarity between different situations and showing how the criteria of similarity change depending on knowledge and other factors. By testing when people spontaneously transfer (in an SPS sense) from one situation to another, researchers can determine the psychologically common elements that cued the replication or application of an idea learned in one situation to the other. For example, it has been very instructive to see that novices often rely on surface similarities, whereas experts find deeper, less apparent structural similarities (e.g., Chi, Feltovich, & Glaser, 1981). Despite the value of the SPS methodology, it often comes with a set of unexamined assumptions about what it means to know and understand. The most important assumption is that ''real transfer'' involves only the direct application of previous learning; we believe that this assumption has unduly limited the field's perspective of what it means to use one's previous learning in a new situation effectively. Unassisted, direct applications of knowledge are important, but they are only part of the picture. The PFL perspective highlights the importance of helping people learn throughout their lives.

A potential danger of the PFL perspective is that it could lead to claims such as ''I'm teaching for future learning, so I don't worry about mastery of content.'' We do not wish to encourage such claims and have emphasized that some activities prepare people for further learning better than others. For example, we have tried to show that well-differentiated knowledge is crucial for future learning (e.g., Schwartz & Bransford, 1998), and we have emphasized the importance of using dynamic assessments to measure the degree to which people's past experiences have prepared them for future learning.

Much work remains to be done to develop the kinds of computer-based dynamic assessments that we described at the end of this chapter. Teachers can do their own dynamic assessments by looking not only at students' performances on tests (which use SPS methodologies) but also at their abilities to learn new sets of materials. Are they using what they know to define learning goals? Are they carefully evaluating new information rather than simply assimilating it to existing schemas? Are they able to work collaboratively with others? Are they reaching sound conclusions based on existing evidence? Are they able to reflect on their learning processes and strategies?

People's ability to dynamically assess their preparedness for learning should itself be knowledge that transfers and helps them learn. This does not, however, mean that it is a general skill or a formal discipline (e.g., see Vye et al., 1989). In agreement with Broudy's (1977) analysis, the PFL perspective suggests that these kinds of activities arise from a well-differentiated knowledge base that students are able to ''know with.'' The ideal scope of that knowledge appears to include the humanities as well as the often-emphasized fields of science and mathematics. The goal of helping people integrate these areas into a coherent framework for ''knowing with'' appears to be an important challenge to pursue.

APPENDIX

A Rough Categorization of Questions Generated by Fifth-Grade and College Students About Creating an Eagle Recovery Plan

5th-grade students

"Basic" Eagle Facts • How much do they weigh full grown? • How big are their bodies? • What is their wingspan? • How big are they? • How high do they fly? • Are they color blind? • What do they look like? • How many are there in the U.S.? • Why do you call them bald eagles?

Habitat Questions • Where do they live? • Where do you find them? • What kinds of trees do they live in?

Development Questions • How do they take care of their babies? • How many eggs do they lay at one time? • How big are their nests? • What age do they fly? • How old do they get?

Foraging Questions • How do they find food? • What do they like to eat? • How do they catch their prey?

College students

Interdependency Questions • What about predators of eagles and eagle babies? • Do other animals need to be recovered in order to recover eagles? • Why save the bald eagle versus other organisms? • What type of ecosystem supports eagles?

Survival Needs Questions • What are the eagles' daily needs? • What kinds of habitat do eagles need to live in, and is there sufficient habitat? • Are today's threats like the initial threats to eagles? • Are there different types of eagles with different needs?

Human Resource and Impact Questions • What are the !aws? • What resources (financial and information) are available to support? • What are the politics of eagles? • What different kinds of specialists are needed for different recovery areas? • What facilities are needed, and transport methods? • What kind of training is necessary to handle an eagle? • What were the detrimental effects of DDT?

Goal- and Plan-Related Questions • What are the goals of current programs? • What is the ultimate goal of population recovery (how many needed)? • Why is there a belief that the population needs to be doubled? • What are the current recovery plans? • What are the eagle recovery regions and how are they working? • What are the most promising recovery methods? • How do people estimate eagle populations? • Why are some states more successful? • What can be learned from the more successful states?

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