Teaching for Transfer

Students often fail to apply knowledge and skills learned in one context to other situations. With well-designed instruction, we can increase the likelihood that they will.

Facing a move across town and concerned with economy, you rent a small truck to transport your worldly possessions. You have never driven a truck before and wonder whether you can manage it. However, when you pick the truck up from the rental agency, you find yourself pleased and surprised. Driving the truck is an experience unfamiliar, yet familiar. You guide the vehicle through the city traffic with caution, yet growing confidence, only hoping that you will not have to parallel park it.

This everyday episode is a story of transfer—something learned in one context has helped in another. The following line of poetry from Shakespeare also shows transfer: "Summer's lease hath all too short a date." Regretting the decline of summer in his Sonnet 18, Shakespeare compares it to, of all things, a lease. The world of landlords and lawyers falls into startling juxtaposition with the world of dazzling days, cumulus clouds, and warm breezes.

Your experience with the truck and Shakespeare's metaphor differ in many ways. From driving a car to driving a truck is a short step, while from leases to summer seems a long step. One might speak roughly of "near transfer" versus "far transfer." In the first case, you carry a physical skill over to another context, whereas, in the second, Shakespeare carries knowledge associated with leases over to another context. One might speak of transfer of skill versus transfer of knowledge, and although here we will focus on those two, other sorts of things might be transferred as well; for instance, attitudes or cognitive styles. Finally, the first case is everyday, the second a high achievement of a literary genius. Nonetheless, despite these many contrasts, both episodes illustrate the phenomenon of transfer. In both, knowledge or skill associated with one context reaches out to enhance another. (It is also possible to speak of negative transfer, where knowledge or skill from one context interferes in another.)

Transfer goes beyond ordinary learning in that the skill or knowledge in question has to travel to a new context—from cars to trucks, from lawyers to summer, or across other gaps that might in principle block it. To be sure, that definition makes for a fuzzy border between transfer and ordinary learning. For example, if car-to-truck is a gap, so in some sense is automatic transmission to standard transmission, or Ford automatic to Chrysler automatic. But the last two and especially the last do not seem intuitively to be different enough to pose a significant gap. In practice, we have a rough sense of what gaps might be significant and, although that sense may not always be accurate, nothing in this article will depend upon drawing a perfectly sharp line between transfer and ordinary learning.

If transfer figures in activities as diverse as moving across town and writing sonnets, it is easy to believe that transfer has at least a potential role in virtually all walks of life. But transfer does not take care of itself, and conventional schooling pays little heed to the problem. With proper attention, we can do much more to teach for transfer than we are now doing.

Why Is Transfer Important to Education?

Any survey of what education hopes to achieve discloses that transfer is integral to our expectations and aspirations for education. First of all, the transfer of basic skills is a routine target of schooling. For example, students learn to read *Dick and Jane* or *A Tale of Two Cities* not just for the sake of reading other texts but in preparation for a much wider range of reading—newspapers, job applications, income tax forms, political platforms, assembly instructions, wills, contracts, and so on. Students learn mathematical skills not just for the sake of figuring Sammy's age when it is two-thirds of Jane's, but for smart shopping in the supermarket, wise investment in the stock market, understanding of statistical trends, and so on.

Another expectation of education concerns the transfer of knowledge. The "data base" students acquire in school ought to inform their thinking in other school subjects and in life outside of school. For example, European and American history should help students to think about current political events—the traditions that shape them, the economic and political factors that influence them, the reasons why one votes or acts in certain ways in the political arena. Literary studies should help students to think about fundamental problems of life—the cycle of birth and death, the struggle for dominance, the quest for love, and how one's own life incarnates those eternal dramas. Science instruction should help students to understand the world around them—the branch waving in the wind as an oscillator, a city as an artificial ecology, the threat and promise of nuclear power or genetic engineering.

Finally, transfer plays a key role in an aspiration of education that lately has attained great prominence: the teaching of thinking skills. As with basic skills and knowledge, here again the aim is not just to build students' performance on a narrow range of school tasks. One hopes that students will become better creative and critical thinkers in the many contexts that invite a thoughtful approach—making important life decisions, casting votes, interacting with others equitably, engaging in productive pursuits such as essay writing, painting, and so on.

Why Is Transfer Worrisome in Education?

The implicit assumption in educational practice has been that transfer takes care of itself. To be lighthearted about a heavy problem, one might call this the "Bo Peep" theory of transfer: "Let them alone and they'll come home, wagging their tails behind them." If students acquire information about the Revolutionary War and the Westward emigration, if they learn some problem-solving skills in math and some critical thinking skills in social studies, all this will more or less automatically spill over to the many other contexts in and out of school where it might apply, we hope.

Unfortunately, considerable research and everyday experience testify that the Bo Peep theory is inordinately optimistic. While the basic skills of reading, writing, and arithmetic typically show transfer (for reasons to be discussed later), other sorts of knowledge and skill very often do not.

For example, a great deal of the knowledge students acquire is "inert" or "passive." The knowledge shows up when students respond to direct probes, such as multiple choice or fill-in-the-blank quizzes. However, students do not transfer the knowledge to problem-solving contexts where they have to think about new situations. For example, Bransford and his colleagues have demonstrated that both everyday knowledge and knowledge acquired in typical school study formats tend to be inert (Bransford et al. 1986, Perfetto et al. 1983). Studies of programming instruction have shown that a considerable portion of beginning students' knowledge of commands in a pro-

Must We Choose Between Cultural Literacy and Critical Thinking?

From certain quarters today comes a wave of pessimism about the prospects of transfer and the potentials of teaching for general cognitive skills. One recent and popular spokesperson for a negative position is E. D. Hirsch, Jr. (1987), who offers in his *Cultural Literacy* an eloquent plea for turning away from general skills and equipping youngsters with the varied basic knowledge that makes one culturally literate.

Such a response is quite understandable in the face of the naive approach to problems of learning and transfer typically found in schools. Often, educators have expected broad global nonspecific transfer from highly specialized activities such as the study of Latin or computer programming, as though these activities exercised up some generic mental muscle. Often, educators have not focused on exactly *what* about such activities might transfer nor made efforts to decontextualize the transferable aspects and bridge them to other contexts. Often, educators have sought to impart lengthy lists of "microskills" for reading or other performances, an approach that seems doomed to sink in the quicksand of its own complexity.

On the other hand, Hirsch and others who would turn their backs on general skills overmake their case. Hirsch, for example, adopts a strong local knowledge position, asserting that the prospects for transfer are meager. However, we argue for the considerable potentials of transfer if attention is paid to fostering it. Throughout *Cultural Literacy*, Hirsch periodically snipes at the teaching of critical thinking, intimating that attention to such general skills pays no dividend. But we emphasize that some aspects of critical thinking plainly call for attention—thinking on the other side of the case, for example.

Ironically, in framing his argument, Hirsch commits one of those lapses of critical thinking he sees no need for schools to address: he creates a false dichotomy, treating as contraries factors that are compatible and indeed complementary. This is one of the most common slips of critical thinking, one that well-designed education could help us all to become more mindful of. Specifically, although basic knowledge of our culture has a commonly neglected importance, as Hirsch argues, this does not imply that critical thinking and other kinds of general knowledge and skill are unimportant. Plainly, more than one thing can be important at the same time. Of course, an articulate monolithic view such as his makes better press. It may even work to correct the opposite excess better than would a balanced appraisal. But it rarely captures the real complexity of human skill and knowledge.

—D. N. Perkins and Gavriel Salomon

gramming language is inert even in the context of active programming, where there is hardly any gap to transfer across (Perkins and Martin 1986, Perkins et al. 1986). Studies of medical education argue that much of the technical knowledge student physicians acquire from texts and lectures is inert—not retrieved or applied in the diagnostic contexts for which it is intended (Barrows and Tamblyn 1980).

It has often been suggested that literacy is one of the most powerful carriers of cognitive abilities. Olson (1976), for example, has argued that written language permits patterns of thinking much more complex than can be managed within the limited capacity of human short-term memory. Moreover, written texts, in their presentational and argument structures, illustrate patterns of thinking useful for handling complex tasks. Literacy, therefore, ought to bring with it a variety of expanded cognitive abilities. To put the matter in terms of transfer, literacy should yield cognitive gains on a number of fronts, not just the skills of reading and writing per se.

The difficulty with testing this hypothesis is that people usually learn to write in schools, at the same time that they learn numerous other skills that could affect their cognitive abilities. This dilemma was resolved when Scribner and Cole (1981) undertook a detailed study of the Vai, an African tribe that had developed a written language which many members of the tribe learned and used, but that maintains no tradition of formal schooling. Remarkably, the investigators' studies disclosed hardly any impact of Vai literacy on the cognitive performance of Vai who had mastered the written language. The hypothesized transfer did not appear.

Another source of discouraging evidence about transfer comes from contemporary studies of the impact of computer programming instruction on cognitive skills. Many psychologists and educators have emphasized that the richness and rigor of computer programming may enhance students' cognitive skills generally (e.g., Feurzeig et al. 1981, Linn 1985, Papert 1980). The learning of programming demands *systematicity*, breaking problems into parts, diagnosing the causes of difficulties, and so on. Thinking of this sort appears applicable to nearly any domain. Moreover, as Papert (1980) has urged, programming languages afford the opportunity to learn about the nature of procedures, and procedures in turn provide a way of thinking about how the mind works. While all this may be true, the track record of efforts to enhance cognitive skills via programming is discouraging. Most findings have been negative (see reviews in Clements 1985b, Dalbey and Linn 1985, Salomon and Perkins 1987).

Another well-investigated aspect of learning has been the effort to teach somewhat retarded individuals the basic cognitive skills of memory. Learning some basic strategies of memory familiar to any normal individual can substantially improve the performance of retarded learners. However, in most cases, the learners do not carry over the strategies to new contexts. Instead, it is as though the memory strategies are "contextually welded" to the circumstances of their acquisition (Belmont et al. 1982).

With this array of findings contrary to the Bo Peep theory, it is natural to ask why transfer should prove so hard to achieve. Several explanations are possible. Perhaps the skill or knowledge in question is not well learned in the first place. Perhaps the skill or knowledge in itself *is* adequately assimilated but *when* to use it is not treated at all in the instruction. Perhaps the hoped-for transfer involves genuine creative discovery—as in the case of Shakespeare's metaphor—that we simply cannot expect to occur routinely.

While all these explanations have a commonsense character, one other contributed by contemporary cognitive psychology is more surprising: there may not be as much to transfer as we think. The skills students acquire in learning to read and write, the knowledge they accumulate in studying the American Revolution, and the problem-solving abilities they develop

Taken together, the notions of bridging and hugging write a relatively simple recipe for teaching for transfer. First, imagine the transfer you want. Next, shape instruction to hug closer to the transfer desired. Also, shape instruction to bridge to the transfer desired.

in math and physics may be much more specific to those contexts than one would imagine. Skill and knowledge are perhaps more specialized than they look. This is sometimes called the problem of "local knowledge"; that is, knowledge (including skill) tends to be local rather than general and crosscutting in character.

The classic example of this problem of local knowledge is chess expertise, which has been extensively researched. Chess is an interesting case in point because it appears to be a game of pure logic. There is no concealed information, as in card games:

all the information is available to both players. It seems that each player need only reason logically and make the best possible move within his or her mental capacity.

However, in contrast with this picture of chess as a general logical pursuit, investigations have disclosed that chess expertise depends to a startling degree on experience specifically with the game. Chess masters have accumulated an enormous repertoire of "schemata"—patterns of a few chess pieces with significance for play (de Groot 1965, Chase and Simon 1973). One pattern may indicate a certain threat, another a certain opportunity, another an avenue of escape. Skilled play depends largely on the size of one's repertoire. A chess player may be no more adept at other intellectual pursuits, such as solving mysteries or proving mathematical theorems, than any layperson.

Findings of this sort are not limited to chess. They have emerged in virtually every performance area carefully studied with the question in mind, including problem solving in math (Schoenfeld and Herrmann 1982), physics (Chi et al. 1981, Larkin 1983, Larkin et al. 1980), and computer programming (Soloway and Ehrlich 1984), for example.

In summary, diverse empirical research on transfer has shown that transfer often does not occur. When transfer fails, many things might have gone wrong. The most discouraging explanation is that knowledge and skill may be too "local" to allow for many of the expectations and aspirations that educators have held.

When Does Transfer Happen?

The prospects of teaching for transfer might be easier to estimate with the help of some model that could explain the mechanisms of transfer and the conditions under which transfer could be expected. Salomon and Perkins (1984) have offered such an account, the "low road/high road" model of transfer. The model has been used to examine the role of transfer in the teaching of thinking (Perkins and Salomon 1987), to forecast the impact of new technologies on cognition (Perkins 1985), and to review the findings on transfer of cognitive skills from programming instruction (Salomon and Perkins 1987).

At the heart of the model lies the distinction between two very different mechanisms of transfer—low road transfer and high road transfer. The way learning to drive a car prepares one for driving a truck illustrates low road transfer. One develops well-practiced habits of car driving over a considerable period. Then one enters a new context, truck driving, with many obvious similarities to the old one. The new context almost automatically activates the patterns of behavior that suit the old one: the steering wheel begs one to steer it, the windshield invites one to look through it, and so on. Fortunately, the old behaviors fit the new context well enough so that they function quite adequately.

To generalize, low road transfer reflects the automatic triggering of well-practiced routines in circumstances where there is considerable perceptual similarity to the original learning context. Opening a chemistry book for the first time triggers reading habits acquired elsewhere, trying out a new video game activates reflexes honed on another one, or interpreting a bar graph in economics automatically musters bar graph interpretation skills acquired in math. This low road transfer trades on the extensive overlap *at the level of the superficial stimulus* among many situations where we might apply a skill or piece of knowledge.

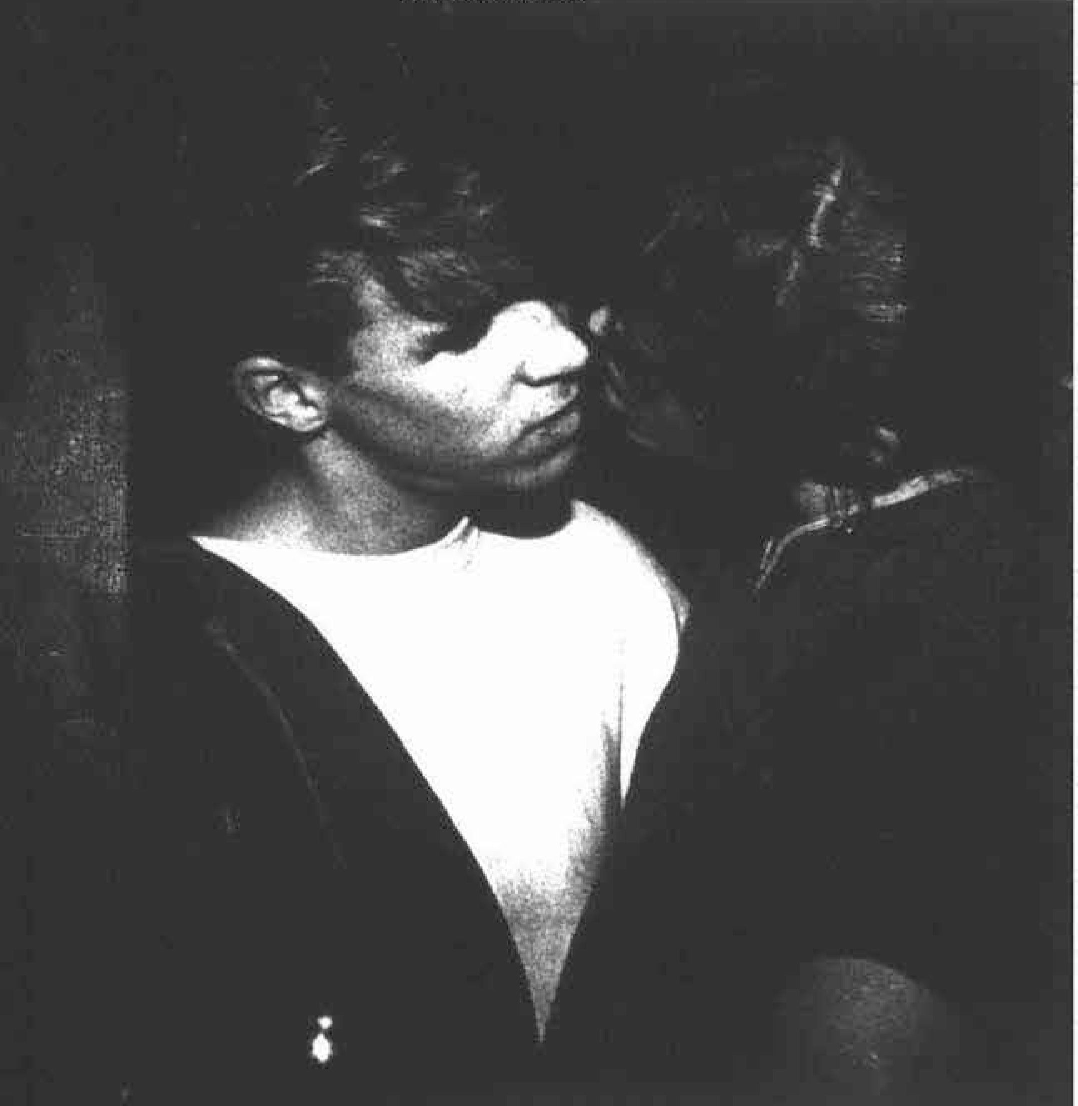
High road transfer has a very different character. By definition, high road transfer depends on deliberate mindful abstraction of skill or knowledge from one context for application in another. Although we know nothing directly of Shakespeare's mental processes, it seems likely that Shakespeare arrived at his remarkable "Summer's lease hath all too short a date" not by tripping over it, but by deliberate authorial effort, reaching mentally for some kind of abstract metaphorical match with the decline of summer. After all, in contrast with the resemblance between car and truck cabs, no superficial perceptual similarity exists between summer's end and leases to provoke a reflexive connection.

Whatever the case with Shakespeare, more everyday examples of high road transfer are in order. It is useful to distinguish between at least two types of high road transfer—forward reaching and backward reaching. In forward-reaching high road transfer, one learns something and abstracts it in preparation for applications elsewhere. For instance, an enthusiastic economics major learning calculus might reflect on how calculus could apply to economic contexts, speculate on possible uses, and perhaps try out some, even though the calculus class does not address economics at all and the economics classes the student is taking do not use advanced math. A chess player might contemplate basic principles of chess strategy, such as control of the center, and reflectively ask what such principles might mean in other contexts—what would control of the center signify in a business, political, or military context?

In backward-reaching high road transfer, one finds oneself in a problem situation, abstracts key characteristics from the situation, and reaches backward into one's experience for matches. The same examples applied in reverse can illustrate this pattern. A different economics major, facing a particular problem, might define its general demands, search her repertoire, and discover that calculus can help. A young politician; developing strategies for the coming campaign, might reflect on the situation and make fertile analogies with prior chess experience: capture the center of public opinion and you've captured the election.

As these examples show, whether forward-reaching or backward-reaching, high road transfer always involves reflective thought in abstracting from one context and seeking connections with others. This contrasts with the reflexive automatic character of low road transfer. Accordingly, high road transfer is not as dependent on super-

Photograph by Lloyd Wolf



When teachers introduce a literary classic with references to the related experiences of their students, as illustrated here, they are creating the conditions for "low road" transfer. Establishing such connections is called "hugging" by Perkins and Salomon.

When teachers point out parallels between elements of content, such as the points of comparison between the treatment of blacks in the United States before the Civil War and in South Africa today, they are facilitating "high road" transfer. This process is called "bridging."

ficial stimulus similarities, since through reflective abstraction a person can often "see through" superficial differences to deeper analogies.

The low road/high road view of transfer helps in understanding when it is reasonable or not to expect transfer because it clarifies the conditions under which different sorts of transfer occur. To be sure, *sometimes* transfer happens quite automatically in accordance with the Bo Peep theory; but that is by the low road, with the requirements of well-practiced skills or knowledge and superficial perceptual similarity to activate the skills or knowledge. Moreover, the transfer is likely to be "near" transfer, since the contexts have that surface perceptual similarity. High road transfer can bridge between contexts remote from one another, but it requires the effort of deliberate abstraction and connection-making and the ingenuity to make the abstractions and discover the connections.

Can Failures of Transfer Be Explained?

We reviewed a number of worrisome failures of transfer earlier. It is by no means the case, though, that conventional education affords no transfer at all. As mentioned earlier, most students learn to read more or less adequately and do bring those reading skills to bear when introduced to new areas. They do apply their arithmetic skills to income tax forms and other out-of-school tasks. Can the low road/high road model help us to understand why education sometimes succeeds but all too often fails in achieving transfer?

Broadly speaking, the successes fit the description of low road transfer. For example, students fairly readily carry over their basic reading skills to many new contexts. But the surface characteristics of those new contexts strongly stimulate reading skills—text appears in front of one's eyes, so what else would one do but read it? Arithmetic skills also transfer readily to such contexts as filling out income tax forms or checking bills in restaurants and stores. But again, the stimulus demand is direct and explicit: the tax forms provide places for sums, differences, and products; the bill displays an addition.

Consider now one of the failures: the problem of inert knowledge. For instance, when students fail to interpret current events in light of their historical knowledge, what can be said about the problems of transfer? First, there is an issue of initial learning: the skill students have learned through their study of history is not the skill they need when they consider today's newspapers. We want them to make thoughtful interpretations of current events, but they have learned to remember and retrieve knowledge on cue. We can hardly expect transfer of a performance that has not been learned in the first place!

However, that aside, what about the conditions for low and high road transfer? As to the low road, there is little surface resemblance between the learned knowledge and the new contexts of application. Why should the current strife between Iraq and Iran automatically remind a student of certain of the causes of the Civil War, when the surface features are so different? As to the high road, this would require explicit mindful abstraction of historical patterns and applications in other settings, to break those patterns free of their accidental associations in the Civil War or other settings. Conventional history instruction does little to decontextualize such patterns, instead highlighting the particular story of particular historical episodes.

We want students to make thoughtful interpretations of current events in light of their historical knowledge, but they have learned to remember and retrieve knowledge on cue. We can hardly expect transfer of a performance that has not been learned in the first place!

Consider another failure: the impact of programming instruction on general cognitive skills. As to low road transfer, in most of the studies seeking transfer from computer programming, the students have not learned the programming skills themselves very well, failing to meet the condition of practice to near automaticity. Moreover, there is a problem with the surface appearance condition for low road transfer. In the context of programming, one might learn good problem-solving practices such as defining the problem clearly before one begins. However, the formal context of programming does not look or feel very much like the tense context of a labor dispute or the excited context of hunting for a new stereo system. Accordingly, other contexts where it is important to take time in defining the problem are not so likely to reawaken in students' minds their programming experiences.

As to high road transfer from programming, this would demand emphasis on abstracting from the programming context general principles of, for instance, problem solving and transporting those principles to applications outside of programming. However, most efforts to teach programming include virtually no attention to building such bridges between domains, but rather focus entirely on building programming skills. So the conditions for high road transfer are not met either.

Similar accounts can be given of the other cases of failure of transfer discussed earlier. In summary, conventional schooling lives up to its earlier characterization as following the Bo Peep theory of transfer—doing nothing special about it but expecting it to happen. When the conditions for low road transfer are met by chance, as in many applications of reading, writing, and arithmetic, transfer occurs—the sheep come home by themselves. Otherwise, the sheep get lost.

To be sure, meeting the low road and high road conditions for transfer is not the whole story. There remains the deeper problem of "local knowledge." The most artful instructional design will not provoke transfer if the knowledge and skills in question are fundamentally local in character, not really transferable to other contexts in the first place. This problem will be revisited shortly.

Can We Teach for Transfer?

Besides accounting for failure of transfer, the foregoing explanations hold forth hope of doing better: by designing instruction to meet the conditions needed to foster transfer, perhaps we can achieve it. In broad terms, one might speak of two techniques for promoting transfer—"hugging" and "bridging."

"Hugging" means teaching so as to better meet the resemblance conditions for low road transfer. Teachers who would like students to use their knowledge of biology in thinking about current ecological problems might introduce that knowledge in the first place in the context of such problems. Teachers who want students to relate literature to everyday life might emphasize literature where the connection is particularly plain for many students—*Catcher in the Rye* or the adolescent pining of Romeo, for example.

"Bridging" means teaching so as to meet better the conditions for high road transfer. Rather than expecting students to achieve transfer spontaneously, one "mediates" the needed processes of abstraction and connection making (Delclos et al. 1985, Feuerstein 1980). For example, teachers can point out explicitly the more general principles behind particular skills or knowl-

Low road transfer reflects the automatic triggering of well-practiced routines in circumstances where there is considerable perceptual similarity to the original learning context. High road transfer is not as dependent on superficial stimulus similarities, since through reflective abstraction a person can often "see through" superficial differences to deeper analogies.

edge or, better, provoke students to attempt such generalizations themselves: what general factors provoked the American Revolution, and where are they operating in the world today? Teachers can ask students to make analogies that reach outside the immediate context: how was treatment of blacks in the U.S. South before the Civil War like or unlike the treatment of blacks in South Africa today? Teachers can directly teach problem-solving and other strategies and provoke broad-spectrum practice reaching beyond their own subject matters: you learned this problem-defining strategy in math, but how might you apply it to planning an essay in English?

Such tactics of hugging and bridging will sound familiar. Teachers already pose questions and organize activities of these sorts from time to time. However, rarely is this done persistently and systematically enough to saturate the context of education with attention to transfer. On the contrary, the occasional bridging question or reading carefully chosen to "hug" a transfer target gets lost amid the overwhelming emphasis on subject matter-specific, topic-specific, fact-based questions and activities.

There is ample reason to believe that bridging and hugging together could do much to foster transfer in instructional settings. Consider, once again, the impact of programming on cognitive skills. As emphasized earlier, findings in general have been negative. However, in a few cases, positive results have appeared (Carver and Klahr 1987; Clements 1985a, b; Clements and Gullo 1984; Clements and Merriman in press; Littlefield et al. in press). These cases all involved strong bridging activities in the instruction.

The same story can be told of efforts to teach retarded persons elementary memory skills. As noted earlier, transfer was lacking in most such experiments—but not in all. In a few experiments, the investigators taught learners not only the memory strategies themselves but habits of self-monitoring, by which the learners examined their own behavior and thought about how to approach a task. This abstract focus on task demands—in effect a form of bridging—led to positive transfer results in these studies (Belmont et al. 1982).

Even without explicit bridging, hugging can have a substantial impact on transfer. For example, inert knowledge has been a serious problem in medical education, where traditionally students memorize multitudinous details of anatomy and physiology outside the context of real diagnostic application. In an approach called "problem-based learning," medical students acquire their technical knowledge of the human body in the context of working through case studies demanding diagnosis (Barrows and Tamblyn 1980). Experiments in science education conducted by John Bransford and his colleagues tell a similar story: when science facts and concepts were presented to students in the context of a story where they figured in resolving a problem or illuminating a question, the students proved much more able to transfer these facts and concepts to new problem-solving contexts (Bransford et al. 1986, Sherwood et al. 1987). In both the medical context and the science work, the instruction hugged much closer to the transfer performance than would instruction that simply and straightforwardly presented information.

Taken together, the notions of bridging and hugging write a relatively simple recipe for teaching for transfer. First, imagine the transfer you want, let us say, interpretation of contemporary and past conduct of societies and nations, or, let us say, problem solving where care is taken to define the problem before seeking solutions. Next, shape instruction to hug closer to the transfer desired. Teach history not just for memorizing its story but for interpretation of events through general principles. Teach programming or mathematical problem solving with emphasis on problem defining. Also, shape instruction to bridge to the transfer desired. Deliberately provoke students to think about how they approach tasks in and outside of history, programming, or math. Steal a little time from the source subject matter to confront students with analogous problems outside its boundary. Such teamwork between bridging and hugging practically guarantees making the most of whatever potential transfer a subject matter affords.

Moreover, there is an opportunity to go even further: aside from how one teaches, one can help students develop skills of *learning for transfer*. Students can become acquainted with the problem of transfer in itself and the tactics of bridging and hugging. Students can develop habits of doing considerable bridging and hugging for themselves, beyond what the instruction itself directly provides. Accordingly, a major goal of teaching for transfer becomes not just teaching particular knowledge and skills for transfer but teaching students in general how to *learn for transfer*.

Although basic knowledge of our culture has a commonly neglected importance, as Hirsch argues, this does not imply that critical thinking and other kinds of general knowledge and skill are unimportant.

Is Knowledge Too Local for Transfer?

Encouraging as all this is, it nonetheless leaves untreated the nagging problem of "local knowledge." If by and large the knowledge (including skills) that empowers a person in a particular activity is highly local to that activity, there are few prospects for useful transfer to other activities. What, then, can be said about this contemporary trend in theorizing about expertise and its implications for the potentials of teaching for transfer?

The suggestion is that, while the findings supporting a "local knowledge" view of expertise are entirely sound, the implications drawn from those findings contra the prospects of transfer are too hasty. Despite the local knowledge results, there are numerous opportunities for transfer. At least three arguments support this viewpoint: (1) disciplinary boundaries are very fuzzy, not representing distinct breaks in the kinds of knowledge or skill that are useful; (2) while much knowledge is local, there are at least a few quite general and important thinking strategies; (3) there are numerous elements of knowledge and skill of intermediate generality that afford some transfer across a limited range of disciplines.

The fuzziness of disciplinary boundaries. Even if knowledge and skill are local, are their boundaries of usefulness the same as the boundaries we use to organize disciplines and subject matters? For a case in point, history and current events might be treated in schools as different subjects; and, because they are partitioned off from each other, one might find scant transfer between them without special attention. Yet it seems plain that the kinds of causal reasoning and types of causes relevant to explaining historical happenings apply just as well to contemporary happenings. For another case in point, literature is a subject to study, life a "subject" to live. Yet plainly most literature treats fundamental themes of concern in life—love, birth, death, acquisition and defense of property, and so on. The relationships between literature and life offer an arena for reflection upon both and for transport of ideas from one to the other and back again.

To generalize, a close look at conventional disciplinary boundaries discloses not a well-defined geography with borders naturally marked by rivers and mountain ranges but, instead, enormous overlap and interrelation. If knowledge and skill are local, the boundaries surely are not the cleavages of the conventional curriculum. Yet because those cleavages are there as part of the organization of schooling, tactics of bridging and hugging are needed to take the numerous opportunities for fertile transfer across the conventional subject matters.

The existence of important crosscutting thinking strategies. There are certainly some strategic patterns of thinking that are important, neglected, and cross-disciplinary in character (see, e.g., Baron 1985a,b; Baron and Sternberg 1986; Chipman et al. 1985; Nickerson et al. 1985; Perkins 1986a,b,c). For example, in virtually all contexts people tend not to give full attention to the other side of the case—the side opposite their own—in reasoning about a claim. For another example, people tend to be "solution minded," orienting too quickly to a problem and beginning to develop candidate solutions at once, when often it would be more effective to stand back from the problem, explore its nature, define exactly what the problem is, seek alternative ways to represent it, and so on. For a third, people tend not to monitor their own mental processes very much, when doing so would garner the perspective and leverage of greater metacognitive awareness.

To be sure, exactly how to consider the other side of the case, explore a problem, or self-monitor is somewhat a matter of local knowledge that will differ significantly from context to context. However, the strategy of allocating attention and effort to considering the other side of the case, exploring a problem, or self-monitoring is fully general. Accordingly, developing such strategies in any domain, one can then hope to transfer them to others.

Patterns of thinking of intermediate generality. Finally, if we do not demand universal generality, there are numerous kinds of knowledge and skill of intermediate generality that cut across certain domains and provide natural prospects for transfer. For example, many considerations of measurement, methodology, and the role of evidence apply fairly uniformly across the hard sciences. Any art yields interesting results when examined through the categories of style and form, although to be sure the particular styles and forms of importance will vary from art to art. Psychological concepts such as motive, intention, inner conflict, the unconscious, and so on have an obvious role to play in interpreting literature, history, current events, and everyday life, and indeed perhaps some role to play in examining scientific discovery.

Of course, conventional subject matter boundaries usually inhibit the emergence of these patterns of thinking of intermediate generality because the style of instruction is so very local that it does not decontextualize the patterns. Bridging and hugging are needed to develop out of the details of the subject matters the overarching principles.

Members of the Same Team

Instead of worrying about which is more important—local knowledge or the more general transferable aspects of knowledge—we should recognize the synergy of local and more general knowledge. To be sure, students who do not know much about history are unlikely to enrich their thinking about the causes of the American Revolution by the general strategy of trying to reflect on both sides of the case, American and British. But students who do not have the habit of reflecting on both sides of a case will not get much depth of understanding out of the history they do know. Similarly, students who lack an understanding of key mathematical concepts will not gain much from the general strategy of trying to define and represent a problem well before they start. But students who lack the habit of trying to define and represent a problem well will often misuse the mathematical concepts they know when the problem is not routine.

So general and local knowledge are not rivals. Rather, they are members of the same team that play different positions. Proper attention to transfer will make the best of both for the sake of deeper and broader knowledge, skill, and understanding.☐

References

Baron, J. B., and R. S. Sternberg, eds. *Teaching Thinking Skills: Theory and Practice.* New York: W. H. Freeman, 1986.

Baron, J. *Rationality and Intelligence.* New York: Cambridge University Press, 1985a.

Baron, J. "What Kinds of Intelligence Components Are Fundamental? In *Thinking and Learning Skills. Volume 2: Current Research and Open Questions*, edited by S. S. Chipman, J. W. Segal, and R. Glaser, pp. 365–390. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1985b.

Barrows, H. S., and R. M. Tamblyn. *Problem-Based Learning: An Approach to Medical Education.* New York: Springer, 1980.

Belmont, J. M., E. C. Butterfield, and R. P. Ferretti. "To Secure Transfer of Training Instruct Self-Management Skills." In *How and How Much Can Intelligence*

Be Increased?, edited by D. K. Detterman and R. J. Sternberg, pp. 147–154. Norwood, N.J.: Ablex, 1982.

Bransford, J. D., J. J. Franks, N. J. Vye, and R. D. Sherwood. "New Approaches to Instruction: Because Wisdom Can't Be Told." Paper presented at the Conference on Similarity and Analogy, University of Illinois, June 1986.

Carver, S. M., and D. Klahr. "Analysis, Instruction, and Transfer of the Components of Debugging Skill." Paper presented at the biennial meeting of the Society for Research in Child Development, Baltimore, Md., April 1987.

Chase, W. C., and H. A. Simon. "Perception in Chess." *Cognitive Psychology* 4 (1973): 55–81.

Chi, M., P. Feltovich, and R. Glaser. "Categorization and Representation of Physics Problems by Experts and Novices." *Cognitive Science* 5 (1981): 121–152.

Chipman, S. F., J. G. Segal, and R. Glaser, eds. *Thinking and Learning Skills. Volume 2: Current Research and Open Questions.* Hillsdale, N.J.: Lawrence Erlbaum Associates, 1985.

Clements, D. H. "Effects of Logo Programming on Cognition, Metacognitive Skills, and Achievement." Presentation at the American Educational Research Association conference, Chicago, April 1985a.

Clements, D. H. "Research on Logo in Education: Is the Turtle Slow But Steady, or Not Even in the Race?" *Computers in the Schools* 2, 2/3 (1985b): 55–71.

Clements, D. H., and D. F. Gullo. "Effects of Computer Programming on Young Children's Cognition." *Journal of Educational Psychology* 76, 6 (1984): 1051–1058.

Clements, D. H., and S. Merriman. "Componential Developments in Logo Programming Environments." In *Teaching and Learning Computer Programming: Multiple Research Perspectives*. Hillsdale, N.J.: Lawrence Erlbaum Associates, in press.

Dalbey, J., and M. C. Linn. "The Demands and Requirements of Computer Programming: A Literature Review." *Journal of Educational Computing Research* 1 (1985): 253–274.

de Groot, A. D. *Thought and Choice in Chess*. The Hague: Mouton, 1965.

Delclos, V. R., J. Littlefield, and J. D. Bransford. "Teaching Thinking Through Logo: The Importance of Method." *Roeper Review* 7, 3 (1985): 153–156.

Feuerstein, R. *Instrumental Enrichment: An Intervention Program for Cognitive Modifiability*. Baltimore: University Park Press, 1980.

Feurzeig, W., P. Horwitz, and R. Nickerson. *Microcomputers in Education* (Report No. 4798). Cambridge, Mass.: Bolt, Beranek, and Newman, 1981.

Hirsch, E. D., Jr. *Cultural Literacy: What Every American Needs to Know*. Boston: Houghton Mifflin, 1987.

Larkin, J. H. "The Role of Problem Representation in Physics. In *Mental Models*, edited by D. Gentner and A. L. Stevens. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1983.

Larkin, J. H., J. McDermott, D. P. Simon, and H. A. Simon. "Modes of Competence in Solving Physics Problems." *Cognitive Science* 4 (1980): 317–345.

Linn, M. C. "The Cognitive Consequences of Programming Instruction in Classrooms." *Educational Researcher* 14 (1985): 14–29.

Littlefield, J., V. Delclos, S. Lever, and J. Bransford. "Learning Logo: Method of Teaching, Transfer of General Skills, Attitudes Toward Computers." In *Teaching and Learning Computer Programming: Multiple Research Perspectives*. Hillsdale, N.J.: Lawrence Erlbaum Associates, in press.

Nickerson, R., D. N. Perkins, and E. Smith. *The Teaching of Thinking*. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1985.

Olson, D. R. "Culture, Technology, and Intellect." In *The Nature of Intelligence*, edited by L. B. Resnick. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1976.

Papert, S. *Mindstorms: Children, Computers, and Powerful Ideas*. New York: Basic Books, 1980.

Perfetto, G. A., J. D. Bransford, and J. J. Franks. "Constraints on Access in a Problem Solving Context. *Memory & Cognition* 11, 1 (1983): 24–31.

Perkins, D. N. "The Fingertip Effect: How Information-Processing Technology Changes Thinking." *Educational Researcher* 14, 7 (1985): 11–17.

Perkins, D. N. *Knowledge as Design*. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1986a.

Perkins, D. N. "Thinking Frames." *Educational Leadership* 43, 8 (1986b): 4–10.

Perkins, D. N. "Thinking Frames: An Integrative Perspective on Teaching Cognitive Skills." In *Teaching Thinking Skills: Theory and Practice*, edited by J. B. Baron and R. S. Sternberg, pp. 41–61. New York: W. H. Freeman, 1986c.

Perkins, D. N., and F. Martin. "Fragile Knowledge and Neglected Strategies in Novice Programmers." In *Empirical Studies of Programmers*, edited by E. Soloway and S. Iyengar, pp. 213–229. Norwood, N.J.: Ablex, 1986.

Perkins, D. N., F. Martin, and M. Farady. *Loci of Difficulty in Learning to Program* (Educational Technology Center technical report). Cambridge, Mass.: Educational Technology Center, Harvard Graduate School of Education, 1986.

Perkins, D., and G. Salomon. "Transfer and Teaching Thinking." In *Thinking: The Second International Conference*, edited by D. N. Perkins, J. Lochhead, and J. Bishop, pp. 285–303. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1987.

Salomon, G., and D. N. Perkins. "Rocky Roads to Transfer: Rethinking Mechanisms of a Neglected Phenomenon." Paper presented at the Conference on Thinking, Harvard Graduate School of Education, Cambridge, Mass., August 1984.

Salomon, G., and D. N. Perkins. "Transfer of Cognitive Skills from Programming: When and How?" *Journal of Educational Computing Research* 3 (1987): 149–169.

Schoenfeld, A. H., and D. J. Herrmann. "Problem Perception and Knowledge Structure in Expert and Novice Mathematical Problem Solvers." *Journal of Experimental Psychology: Learning, Memory, and Cognition* 8 (1982): 484–494.

Scribner, S., and M. Cole. *The Psychology of Literacy*. Cambridge, Mass.: Harvard University Press, 1981.

Sherwood, R. D., C. K. Kinzer, J. D. Bransford, and J. J. Franks. "Some Benefits of Creating Macro-Contexts for Science Instruction: Initial Findings." *Journal of Research in Science Teaching* 24 (1987): 417–435.

Soloway, E., and K. Ehrlich. "Empirical Studies of Programming Knowledge." *IEEE Transactions on Software Engineering* SE-10, 5 (1984): 595–609.

Authors' note: Some of the ideas discussed here were developed at the Educational Technology Center of the Harvard Graduate School of Education, operating with support from the Office of Educational Research and Improvement (contract #OERI 400-83-0041). Opinions expressed herein are not necessarily shared by OERI and do not represent Office policy.

D. N. Perkins is Co-Director, Project Zero and the Educational Technology Center, Harvard University, Graduate School of Education, 315 Longfellow Hall, Appian Way, Cambridge, MA 02138. **Gavriel Salomon** is a Professor at the University of Tel Aviv and at the College of Education, University of Arizona, Tucson, AZ 85721.