The Science and Art of Transfer

D. N. Perkins and Gavriel Salomon

Transfer at Risk

Both the meaning and the challenge of ``transfer of learning'' are well-expressed in a story told to one of us by a disappointed professor of physics at a nearby college. Among the stock problems explored in the physics course was one like this: ``A ball weighing three kilograms is dropped from the top of a hundred meter tower. How many seconds does it take to reach the ground?'' (Aficionados of physics will recognize that the weight of the ball has nothing to do with the problem; it is a distraction. The answer depends only on the acceleration of gravity.)

On the final exam, the professor included a problem like this: ``There is a one-hundred meter hole in the ground. A ball weighing three kilograms is rolled off the side into the hole. How long does it take to reach the bottom?''

Some students did not recognize the connection between the ``tower'' problem and the ``hole'' problem. One student even came up after the exam and accosted the professor with a complaint. ``I think that this exam was unfair,'' the student wailed. ``We never had any *hole* problems!''

Two points become plain from this anecdote. First of all, it tells us what transfer means. The term ``transfer'' applies when something learned in one situation gets carried over to another - in this case, from the context of ``tower'' problems to the context of ``hole'' problems. Second, the anecdote warns us that all is not well with transfer. Very often, in instructional settings (and in everyday life) we do not get the transfer we want. Learners acquire skills and knowledge in one situation and fail to make connections to other situations where those skills and knowledge would prove valuable.

If transfer does not occur as frequently or as readily as we would like, then this poses a major problem for education. After all, the entire enterprise of formal education depends on transfer. We do not teach students arithmetic in school so that they can apply it on school quizzes and exams; we want them to put arithmetic to work in the world, making wise purchases in the supermarket, understanding their mortgages, keeping track of household expenses, and of course entering careers where arithmetic and more complex kinds of mathematics play key roles. We do not teach students history in school so that they can pass the exam at the end of the term.

Rather, we want them to understand the world they live in from an historical perspective. We want the newspaper headlines to make sense in comparison and contrast with the past. We do not teach students reading and writing in schools so that they can go to the encyclopedia and produce schoolish essays to satisfy the teacher. We want them to be intelligent readers and practical, effective writers in their lives.

These routine ambitions of education all ask that learners apply outside of school what they learn in school. It's worth adding that even within the walls of the school transfer has value. Students need in science classes what they learn in mathematics classes. They need in history classes the writing and reading skills they acquire in English class. All this depends on transfer of learning. If transfer of learning is at risk, much of the point and process of schooling is at risk as well.

What is Transfer of Learning?

While the remarks to this point give a broad sense of the meaning of transfer, it is worthwhile to frame the concept a little more carefully. The concept of transfer basically comes from the psychological literature on learning theory. It means, as said before, the use of knowledge or skill acquired in one context in another (Cromier & Hagman, 1987; Royer, 1979; Salomon & Perkins, 1989).

One important albeit rough contrast concerns *near transfer* versus *far transfer*. Near transfer occurs when knowledge or skill gets used in situations very like the initial context of learning. For instance, transfer from the ``tower'' problem to the ``hole'' problem certainly would count as near transfer. *Far transfer* occurs when people make connections to contexts that intuitively seem vastly different from the context of learning. For example, a friend of one of us, out on a cheese-and-wine picnic, found himself without a knife to cut the cheese and cut the cheese with a credit card instead (don't leave home without it!). He transferred his knowledge of the characteristics of a credit card (stiff, thin) to an application in a radically different context (Perkins, 1990).

It must be admitted that the near-far contrast is very fuzzy. Psychology has failed to articulate a good yardstick to quantify the ``distance'' from context to context, and indeed there are fundamental reasons to believe that any precise yardstick is impossible (Salomon & Perkins, 1989). Nonetheless, the contrast proves useful in broad talk about transfer, particularly because it is far transfer that proves hardest to come by. Yet, far transfer is of special concern to education, since many of the settings where we would like youngsters to apply what they learn in school are not very much like classrooms or the tasks in classrooms through which students initially learn.

Another important contrast in the literature on transfer concerns *positive* versus *negative* transfer. So far, our examples have emphasized positive cases. But transfer of learning can do mischief as well as good. For example, if you have acquired your driving habits in the United

States and rent a car in England on holiday, where folks drive on the left rather than on the right, you will find yourself constantly fighting a disastrous ``drive-on-the-right" impulse- negative transfer. In foreign language learning, many students carry over to the new language syntactic patterns from their original language that do not fit, another case of negative transfer. While the phenomenon of negative transfer is very real and important, on the whole it is much less pressing than the *absence* of positive transfer in the many cases where we want it. Accordingly, we will focus on positive transfer here.

A final crucial contrast concerns *transfer* versus plain old *learning.* Arguably, even minimal learning entails transfer in some sense. If, for example, Doris learns an arithmetic fact in classroom 13a, we would expect her to be able to remember it in classroom 13b despite the fact that the physical arrangement of this room, its furniture, lighting, and wall papers are all quite different from room 13a (otherwise, we would say she had not really learned it in the first place). Yet this is transfer of a sort - from classroom 13a to 13b. So where should we draw the learn between plain old learning and ``real" transfer?

The distinction here is admittedly fuzzy, much like the distinction between near transfer and far transfer. However, the spirit of the contrast is clear enough. Psychologists speak of transfer of learning when it is reasonable to say that the learner *has* learned something within a limited range of contexts (for instance, independent of physical locations such as classrooms 13a and 13b), but whether the learner carries this over to other contexts is at risk. In other words, transfer begins where minimal learning ends. Another way to make the point would be to extend the near-far contrast to speak of very near transfer, near transfer, and far transfer. ``Very near transfer" is simply normal learning. Given normal learning, then comes the question whether we see near transfer, or even far transfer. Regrettably, often we do not.

The Science of Transfer

Readers may have noticed an oddity in our title: Usually one speaks of the ``art and science" of something, whereas we refer to the ``Science and Art" of transfer. This is no accident. In the case of transfer, at least, a science is very much needed to drive the art.

Historically, transfer has been a frequent concern of educational psychologists. However, it has not so much occupied the attention of practitioners, and the science of transfer itself has taken some odd turns. To meet the challenge of teaching for transfer, it's worth understanding better what theories of transfer we might hold and which capture the phenomenon best. In fact, to lighten the tone a little, we will write about three view of transfer: The Bo Peep theory, the Lost Sheep theory, and the Good Shepherd theory. Each has a contribution to make to understanding when and why transfer happens and how to encourage it to happen more often.

The Bo Peep Theory of Transfer

The Bo Peep theory of transfer is the default theory of educational practice. Year in year out, we teach as though transfer takes care of itself. Youngsters study arithmetic in mathematics class, reading and writing in English, history and social patterns in social studies, and so on, with the expectation that they will more or less automatically carry over what they learn to other appropriate contexts in school and out. Nothing special is done to see that this happens. It is simply supposed to happen.

One might call this the Bo Peep theory of transfer, recalling a couple of the lines from the well-known children's rhyme: ``Leave them alone and they'll come home / wagging their tales behind them." As with Bo Peep's lost sheep, the Bo Peep theory of transfer assumes that knowledge and skill a person has learned anywhere will ``come home" to wherever it is needed. Just leave it alone. No problem.

Who espouses the Bo Peep theory? No one, of course. It is a tacit theory, not articulated, but implicit in the way we behave in the classroom. It is not that anyone advocates that transfer takes care of itself. Rather, everyday practice presumes that this happens. Unfortunately, the lesson of both more carefully scrutinized experience and of considerable psychological research is that transfer very often does not occur spontaneously.

The classic contribution of the psychological laboratory to this argument comes from the early educational psychologist E. L Thorndike. Thorndike first studied the transfer effects of specific activities such as crossing out a particular letter on one page on one's ability to cross out another letter on another page. Later on, testing the idea that specific subject areas (e.g., Latin) cultivate the mind's faculties, he compared the curricular areas of literally thousands of students. In this way Thorndike could examine the extent to which any one curricular combination affected students' abilities, as compared with another.

Thorndike's research led him to conclude that no transfer from one area to another takes place unless the two share a number of important common elements. The implication is that learning is highly specific: ``training the mind means the development of thousands of particular independent capacities" (Thorndike, 1906, p. 246). Considerable further research since Thorndike's day has encouraged the same view: very commonly, transfer does not occur in the absence of blatant similarities between the originally learned task and the transfer task (e.g. Pea & Kurland, 1984a, b; Scribner & Cole, 1981; Simon & Hayes, 1977).

The Lost Sheep Theory of Transfer

As the studies just mentioned show, transfer often simply does not occur. What to make of this? One reaction of the psychological community has also incorporated a line of recent research into what is commonly called *expertise:* the nature of experts' skill in a domain such as physics, painting, or the stock market. The general tenor of this research shows that each domain involves considerable ``local knowledge'' - knowledge quite specific to the particular character of the domain. Knowledge and skill from other domains simply do not inform skilled performance in the domain to any great extent, so, at least, several investigators have concluded.

Combining these investigations with the poor showing of transfer, some psychologists have decided that we do not see the transfer we want simply because the prospects for transfer are poor. Knowledge acquired in one context does not apply that powerfully in other contexts. There is little useful transfer to be had. One might call this viewpoint the Lost Sheep theory of transfer. It says that, in effect, rich far-reaching transfer is a lost cause. One cannot expect to secure very much of it.

Strong implications follow for the design of educational practice. If we believe the Lost Sheep theory, we should more or less give up on the agenda of transfer, particularly far transfer but even many kinds of near transfer. We should shape education to teach in carefully targeted ways specifically to the performances that we want. We should beware of the notion of generally equipping learners with widely applicable knowledge and skill, and instead identify very particular performance targets and adjust education to serve them.

However, is the Lost Sheep theory correct? Perhaps not. A number of findings have emerged in recent years that cast doubt on the Lost Sheep theory. Consider a few examples. Lehman, Lempert, and Nisbett (1988) found that students who attended graduate programs in psychology or medicine (but not chemistry) produced impressive transfer effects on their ability to reason statistically and to think conditionally.

Palincsar and Brown (1984) taught seventh grade poor readers four self-guidance reading comprehension strategies (questioning, clarifying, summarizing, and predicting) through a means that they term ``reciprocal teaching.'' In the reciprocal teaching setting, students take turns in leading their peers in the use of these strategies during reading, initially with strong leadership from the teacher. Reciprocal teaching of these strategies not only improved reading comprehension but also improved students' performance in other domains - the learning of science and social studies - suggesting far transfer of the self-guidance ability cultivated during reciprocal teaching.

Salomon, Globerson, and Guterman (1989) found similar transfer effects from reading with a computerized Reading Partner that provided expert-like advise to writing. It appeared that the seventh grade students in that study internalized the guidance provided by the computer tool and came to use it as self-guidance in a far transfer task - writing.

The Good Shepherd Theory of Transfer

As the foregoing findings - and others too - show, the prospects of transfer are oddly mixed. The Bo Peep theory is wrong: We cannot simply expect that the ``sheep will come home" routinely. On the other hand, the Lost Sheep theory appears to be mistaken too. Sometimes considerable transfer occurs, even far transfer. What to make of this peculiar melange of findings?

Some help comes from a model of transfer recently proposed by your authors, Gavriel Salomon and David Perkins. Salomon and Perkins articulated a ``high-road low-road" model of transfer to explain the complicated pattern of findings. According to their model, transfer occurs in two very different ways, through the high-road mechanism or the low-road mechanism (Perkins & Salomon, 1988; Salomon & Perkins, 1989). Transfer appears only when the conditions activate one or the other mechanism. Findings on transfer are mixed because some educational settings activate one or the other of these mechanisms whereas many educational settings activate neither one.

We will sketch in the high-road low-road model shortly, but it's worth drawing the moral in advance. We cannot expect education to yield much transfer unless it activates the mechanisms of transfer. Accordingly, teachers, textbook writers, and others need to work to ``shepherd" transfer. We need to be proactive about establishing the conditions in the classroom that favor transfer of learning. If we do not, we will miss much of the transfer we want. If we do not, the sheep will get lost. Thus we can speak of the ``Good Shepherd" theory of transfer, that says the desired transfer can occur, but only if we are good shepherds and help it along.

Now let us see what this high-road low-road theory of transfer is like. Consider two cases. In the first case, a friend of your son comes to visit for a few days while his parents are away. Used to reminding your son to pick up after himself, you treat the friend the same way. The friend proves responsive and the house stays neat. Only afterwards do you note that you behaved more or less automatically: ``a kid is a kid." Your behavior transferred from your son to the visitor.

In the second case you face a problem: The more you urge your son to do his homework, the less he does. You wonder and search for an explanation and a solution. Your search suggests to you a principle you have learned in another context: Under some conditions, a perfectly reasonable solution to a problem may end up exacerbating it. You decide that this applies to your case, leading to a conjecture: just maybe your son will become more involved in homework if you only leave it to him rather than pestering him. You try it and find that (in this case at least) it works. Your son starts tackling his homework with more of a will.

Both cases illustrate transfer. But the processes underlying the two are clearly different. In the first case, transfer of a well mastered skill appears to take care of itself when an appropriate situation is encountered. It happens automatically. We call this the *low-road to transfer*. It is based on a skill, mastered to near automaticity by continuous and repeated practice. The skill is applied to a new situation that is very similar to the situations in which it has been practiced in the past. No *far* transfer takes place via the low road, but the transfer that does take place is easy and automatic. Sometimes it is even too automatic: your tendency to drive in London on the right despite your knowledge that the right is the wrong side is an example of low road *negative*

transfer.

Contrast this automatic application of a well practiced skill, typical to low-road transfer, with the second case. Nothing was automatic there. On the contrary, you had to engage in an effortful, deliberate search of your memory to come up with a reasonable answer to your family problem. Moreover, the idea you arrived at was not a well rehearsed low level one; it was a rather general and abstract principle which you must have heard or formulated for yourself awhile ago. Originally, you may have encountered this principle in the context of crime and imprisonment. But once abstracted and freed from its original context, the principle of ``solutions can exacerbate the problems they are designed to solve" becomes available for far and wide application. Transfer to new situations is not easy and it does not happen on its own; it requires the mindful abstraction of a principle, the effortful search in one's memory, the selection of the appropriate principle and, finally, its application to a new instance. Thus we call i*thigh-road transfer*. The cases we have briefly described before - the study of transfer from graduate studies, and the transfer of self-guidance in the Palincsar & Brown (1984) and in the Salomon et al. (1989) studies - were all cases of high road transfer.

The Art of Transfer

The advancing science of transfer paints a more hopeful picture than either the tacit Bo Peep theory or the pessimistic Lost Sheep theory offers. We can have transfer, it seems, if only we will be good shepherds of transfer. But what is the art of shepherding transfer like? How can classroom teachers take advantage of the high road and low road transfer mechanisms to teach for transfer?

Actually it is not too difficult to translate the high-road and low-road mechanisms into some practical advice concerning teaching for transfer. One can speak of two broad categories of classroom practice corresponding to the two mechanisms: *bridging* for high-road transfer and *hugging* for low-road transfer (Perkins & Salomon, 1988). Let us look at each in turn.

Teaching for Transfer by Bridging

In keeping with its name, ``bridging" means that the teacher helps the students to build a bridge from the context of learning to other contexts of potential application. What this might mean is best seen through examples.

Imagine, for instance, a teacher discussing a familiar element of the biology curriculum with students: the circulatory system. After exploring the circulatory system in a fairly traditional way, the teacher, aware of the problem of transfer, decides to provoke a wide-ranging examination of

circulatory systems *in general.*

Teacher. We've been focussing on the human circulatory system. Let's see whether we can think of some *other* circulatory systems. Where else besides in the human body to things circulate?

Students. No response.

Teacher. Well, for example, do things circulate in your home? Or around a city?

With the stimulus of this follow-up questions, the students begin to make connections.

Various students. There's plumbing in your home. There's electricity. Cars circulate around a city. And busses. And oil pipelines carry oil around.

Teacher. Yes, those all make sense. (The teacher lists the examples on the blackboard.) Let's do a quick comparison and contrast for some of these. Take the plumbing in your house, for example. What's a key similarity and a key difference with the human circulatory system?

Student. In the plumbing, a key similarity is it's liquid, and it's used and the waste is excreted - sent to the sewers.

Student. A key difference is that it's not oxygen or nourishment that gets delivered. It's water itself.

The teacher continues with the discussion, drawing out a number of key differences and similarities with various other circulatory systems. Then the teacher seeks to consolidate the experience by extracting some key insights about circulatory systems in general.

Teacher. Let's stand back and see what we're learning from this. What's *common* to all or most of the circulatory systems we've looked at? And *Why?*

Student. Well, one thing is that things tend to go in one direction, except for two-way streets. It's pretty much one-way flow.

Teacher. And why is that?

Student. I guess it's because otherwise the flow wouldn't be very smooth. That's why we have one-way streets. And why we have to drive on one side even when streets are two-way, come to think of it. And how can water or blood or anything flow two ways in the same pipe? Well, maybe it could for a little bit, but not much really.

The teacher continues to discuss the example with the students, extracting a few more fundamental features of circulatory systems. Pleased with the far-ranging discussion, the teacher sees two gains. On the one hand, the students have gotten at something far more general than the original topic of the circulatory system in itself. On the other, they appreciate better the basic ``logic" of the human circulatory system, how it has certain design characteristics fundamental to any circulatory system.

This is just one example of ``bridging." The teacher's questions, calling for analogies and the reasons for them, provoke students to build conceptual bridges between one area - the human circulatory system - and others. Notice how the teacher's questions depend on the high-road mechanism of transfer. They demand of the students mindful abstraction from the case at hand, rather than the automatic reflexive match-making characteristic of low-road transfer.

Of course, this example illustrates just one way in which teachers can bridge. Here are a few other bridging patterns:

- In introducing a new topic, the teacher can ask students to brainstorm how what they learn from it might apply elsewhere, to establish a mindset for transfer.
- After studying a particular topic, say the circulatory system again, the teacher can guide students in a close exploration of *one* analogy, to explore in detail its similarities and contrasts and the underlying reasons for them. For instance, the human circulatory system could be compared in detail with that of a frog.
- The teacher can encourage students to be ``metacognitive" about their approach to solving problems. They can take a minute before tackling a problem to ask what advice they would give themselves about how to approach it. And a minute after to ask how the advice worked out and how they would change it for next time. Research shows that metacognition (roughly, thinking about your thinking) fosters transfer.

In general, the ultimate art in teaching for transfer consists in helping students to catch the spirit and craft of transfer themselves. The teacher does not have to keep reminding them: Once their minds are set for transfer, they will begin spontaneously to look for the connections that earlier had to be provoked.

Teaching for Transfer by Hugging

Of course, bridging exercises just one of the mechanisms of transfer, the high road. How about the low-road mechanism? For this, we adopt the label ``hugging." The general idea of hugging is to make the learning situation *more like* the situations to which transfer is desired. Then the automatic reflexive triggering of responses will frequently occur.

Again, an example serves best to convey the spirit of hugging. Any school child learns about the writing of paragraphs with good topic sentences. But what kind of practice do students receive? Actually, rather different kinds, depending on the text. For instance, children may be asked to scan a list of sentences, marking which ones seem like topic sentences and which like supporting sentences. Children may be asked to review a page full of paragraphs, circling the topic sentences in each paragraph.

Such exercises no doubt have some utility. But they do not go far enough. While the instruction aims to empower students to write better, these activities do not involve any actual writing! In other words, the practice does not ``hug" closely to the desired performance.

How might we provide practice that more directly engages students in writing paragraphs with topic sentences? There are a number of ways. For example, the teacher might hand out slips of paper that ask each student to write a paragraph with a topic sentence. Some students are to place their topic sentences near the end of the paragraph, some near the beginning, just as the textbook allows. After composing their paragraphs, students exchange sheets of paper with their neighbors. Can the neighbor circle the topic sentence in the paragraph? If not, either the author has not written a very conspicuous topic sentences, or the neighbor has not caught on to the idea

of topic sentences (and of course the teacher can help to sort out uncertainties). This kind of activity provides *both* practice in discriminating *and* composing topic sentences.

Regrettably, learning about topic sentences without actually writing any signifies a pattern that recurs all too often in schools: Instruction aims at certain performances, but students do not actually engage in the performances desired nor anything like them. A classic example concerns many physics and chemistry laboratory exercises. Such experiences aim in part to give students the flavor of functioning as a scientist. But most laboratory exercises involve following prescribed recipes. They involve none of the exploratory hypothesis making and inventing of ways to test hypotheses characteristic of real experimental inquiry. It is not so difficult to design laboratory experiences that do exactly this - that ``hug" closer to the experience of authentic scientific inquiry.

Just as in the case of bridging, there are a number of different strategies for fostering transfer by hugging. Here are a few more.

- Simulation games allow students to experience what it is like to be involved in complex patterns of social interaction. For example, students can be assigned to play different roles in a racial or union-management dispute.
- "Problem-based learning" is a pattern of learning that, according to research, fosters transfer. Here, students learn a body of content not didactically but through tackling problems that demand use of the content, studying the content as they need it. This is hugging because knowledge acquired in a problem-solving manner is more available in later problem-solving situations.
- Mental practice is one of the most basic kinds of hugging. When learners cannot actually physically engage in an activity, often useful mental practice is possible. For example, in preparing for a job interview, students can imagine what it would be like, making a ``mental movie" of what the interviewer might ask and how they might answer. (Also, of course, students can rehearse interviews with other students.) A wide range of circumstances invite mental practice, including exam-taking; teachers can encourage students to adopt this powerful tactic often.

Toward the Connected Curriculum

We have shown how a better understanding of the mechanisms of transfer points the way toward instructional practices that foster transfer. No more is there much excuse for letting knowledge accumulate in isolated puddles within students' minds. We know how to teach for transfer, not according to the tacit Bo Peep model where transfer takes care of itself, but according to the Good Shepherd model where teachers need to be proactive cultivators of the conditions for transfer.

The implications of this understanding reach beyond teaching for transfer as such and into the

design of school curricula themselves. To a dismaying extent, education suffers from what might be called a ``disconnected curriculum" (Perkins, 1986). The subject matters are taught in ways encapsulated from one another and sealed off from the lives students live outside of school, not to mention the lives they will live after they have completed their schooling. Partly, this is a problem of transfer. But partly, the disconnected curriculum reflects traditions that have become entrenched in educational practice: A good deal of what youngsters learn does not connect very well to anything else but the class in which it is taught.

A better understanding of transfer of learning and the conditions that foster transfer can help us to look toward the very opposite of the disconnected curriculum - the ``connected curriculum." Teachers, textbook writers, and others concerned with curriculum can more and more make their curricular choices with the potentials of transfer in mind. In selecting topics in history, they can ask themselves about the potential connections to current events, science, the work place, English. In selecting topics in science, they can ask how such topics are likely to speak to the other subject matters, the activities students are likely to be doing after school, the career directions they are likely to be considering.

In general, there is an immense opportunity to consider each subject not only from its own disciplinary perspective but from the standpoint of its potential broader import. Because the science and art of transfer tells us how to make the most of that import, the potential of the connected curriculum is at hand.

References

Cromier, S. M., & Hagman, J. D. (Eds.) (1987). *Transfer of learning.* New York: Academic Press.

Lehman, D. R., Lempert, R. O., & Nisbett, R. E. (1988). The effects of graduate training on reasoning: Formal discipline and thinking about everyday-life events. *American Psychologist, 43,* 431-442.

Palincsar, A. S. & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities. *Cognition and Instruction, 1,* 117-175.

Pea, R. D., & Kurland, D. M. (1984a). On the cognitive effects of learning computer programming. *New Ideas in Psychology, 2*(2), 137-168.

Pea, R. D., & Kurland, D. M. (1984b). *Logo programming and the development of planning skills* (Report no. 16). New York: Bank Street College.

Perkins, D. N. (1986a). *Knowledge as design.* Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Perkins, D. N. (1990). The nature and nurture of creativity. In Jones, B.F., & Idol, L. (Eds.), *Dimensions of thinking and cognition instruction.* Hillsdale, NJ: Lawrence Erlbaum.

Royer, J. M. (1979). Theories of the transfer of learning. *Educational Psychology, 14,* 53-64.

Salomon, G., & Perkins, D. N. (1989). Rocky roads to transfer: Rethinking mechanisms of a neglected phenomenon. *Educational Psychologist, 24*(2), 113-142.

Salomon, G., Globerson, T., & Guterman, E. (1989). The computer as the zone of proximal development: Internalizing reading-related metacognitions from a Reading Partner. *Journal of Educational Psychology, 81,* 620-627.

Scribner, S. & Cole, M. (1981). *The psychology of literacy*. Cambridge, Massachusetts: Harvard University Press.

Simon, H. A., & Hayes, J. R. (1977). Psychological differences among problem isomorphs. In N. J Castelan, D. B. Pisoni, & G. R. Potts (Eds.), *Cognitive theory* (Vol. 2). Hillsdale, NJ: Erlbaum.

Thorndike, E. L. (1906). *Principles of teaching*. New York: A. G. Seiler.