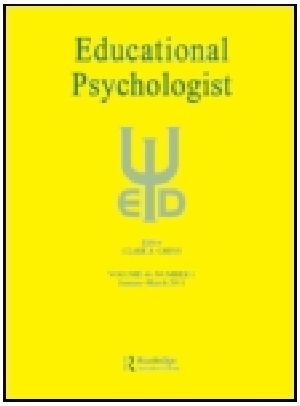

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# Resisting Overzealous Transfer: Coordinating Previously Successful Routines With Needs for New Learning

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# Resisting Overzealous Transfer: Coordinating Previously Successful Routines With Needs for New Learning

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Many approaches to instruction focus on helping people learn to recognize "the old in the new"—to turn what would otherwise be novel problems into familiar patterns that can be solved efficiently through the reuse of prior learning. Instruction that leads to efficient transfer is important, but it can also promote what we call "overzealous" transfer (OZT), where people focus primarily on seeing the old in the new because old routines have been successful before. As a result, OZT can hinder opportunities for new learning, and this can further diminish adaptive transfer later on. We relate OZT to "negative transfer," provide experimental examples of OZT, discuss how a number of professions have developed procedures for avoiding OZT, argue that many common approaches to instruction and assessment may inadvertently produce OZT, and suggest some implications for future research.

Heraclitus, a famous pre-Socratic philosopher, stated that no two experiences are identical; people never step into the same river twice. Nevertheless, people do find consistency in variation and see the same river, even if it contains different water from moment to moment. If people experienced every situation as completely novel, the demands of constant adaptation would make life intolerable. But if people treated every experience as the same, life would be impossible. Transfer research asks how people strike the balance between reusing previous learning to treat new situations like old ones, while also avoiding the tendency to overgeneralize prior learning and miss what is new.

Hatano and Inagaki (1986) noted that some people (routine experts) restrict themselves to familiar settings and challenges that limit their need to see novelty. Others (adaptive experts) are more likely to move outside of existing comfort zones to take on new challenges that require transfer plus some adaptation to meet contextual variation. We frame our discussion with the goals of helping people to be more adaptive, even if they never have the opportunity to become adaptive experts.

## FAILED TRANSFER AND POSITIVE TRANSFER

### Failed Transfer

The phenomenon of transfer has been explored from many perspectives, for example, how identities cross participation boundaries (Beach, 1999) or how foundational capacities such as executive function can support many tasks (Blair & Razza, 2007). Educators have been especially concerned with people's frequent failures to transfer learning from problem

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to problem and from setting to setting (see Bransford et al., 2006; National Research Council [NRC], 2000). Whitehead (1929) coined the term "inert knowledge" to describe cases where people have learned relevant knowledge and skills yet fail to spontaneously access this knowledge despite its relevance for problem solving. Examples include failures to transfer skills and knowledge learned in school to real life settings (Lave, 1988), failures to utilize cues for problem solving unless explicitly instructed to do so (e.g., Lockhart, Lamon, & Gick, 1988; Perfetto, Bransford, & Franks, 1983), failures to use recently learned problem solutions to solve an analogous problem where the cover story has changed (Gick & Holyoak, 1983), and failures to use expertise in one area to solve problems in another (Chase, in press).

### Positive Transfer

To overcome transfer failures, a major strategy is to help people learn to "see the old in the new." Chi and VanLehn (2012/this issue) summarize the cognitive literature: "Transfer can be broadly construed as the ability of individuals to 'treat' a new concept, problem, or phenomenon as similar to one(s) they have experienced before" (p. 177). From this perspective, schools emphasize transfer because it is resource effective—it is easier to reuse than create afresh.

Researchers have studied a variety of instructional strategies for decreasing failed transfer and increasing positive transfer. Wertheimer (1959) provided a classic example of helping students think about geometric area that subsequently supported transfer from a simple figure to a new figure with more complexity. Without his new approach to instruction, students looked at the new transfer problem and tended to say they had never seen it before (e.g., see NRC, 2000).

Gick and Holyoak's (1983) classic studies also show how a problem solution can fail to support transfer to a similar problem if the later problem has a different cover story and occurs a mere two pages later. However, if people first have a chance to make the connection between two analogous problems, then they make the transfer to the next problem much better (see also Brown & Kane, 1988). Transfer is often aided by seeing the same idea in at least two different contexts (NRC, 2000). In other cases, transfer improves if ideas are initially presented in ways that are problematized rather than simply presented as declarative statements (e.g., Adams et al., 1988; Martin et al., 2007; Needham & Begg, 1991). Instruction that helps students differentiate the applicability conditions of problem solutions also improves transfer because people can better recognize contextual cues for the use of their knowledge (Bransford, Franks, Vye, & Sherwood, 1989).

Researchers have also shown that many traditional transfer measures are not sensitive enough to reveal important learning experiences that support transfer from one situation to another. Most assessments used in transfer research are "one shot" rather than iterative (people answer one problem and move to another unrelated problem) and "sequestered" in the sense that people have no access to resources for new learning. As argued elsewhere (Bransford & Schwartz, 1999), sequestered problem solving often represents too blunt an instrument for discovering whether and why previous experiences have prepared people to transfer for future learning, for example, by preparing them to understand a lecture, notice new things, ask more relevant questions, seek feedback, and do other things as they engage in (what need to be) information-rich transfer tasks.

Overall, it seems fair to claim that knowledge of how to improve positive transfer and how to measure it with more sensitivity has improved considerably over the years. Still, all is not well with respect to understanding positive transfer. Many examples of negative transfer still abound, and many routines for learning represent instances of negative transfer.

## NEGATIVE TRANSFER AND OVERZEALOUS TRANSFER

### Negative Transfer

Negative transfer refers to the overgeneralization of prior learning. With negative transfer, people do not fail to transfer; instead, they transfer learning to a situation where it is inappropriate to do so (e.g., Ross, 1987). From early on, the transfer literature recognized problems of negative transfer, where previous learning hurts new learning and problem solving. In many instances, negative transfer appears as interference that people recognize but cannot overcome at first. For instance, verbal learning research asked participants to associate stimuli in Set A with responses defined by Set B (e.g., tree → ball; car → house). This association subsequently interfered with the participants' abilities to learn the association of the stimuli in Set A with a new set of responses defined by Set C (e.g., now learn tree → chair, instead of tree → ball). Similarly, switching from a car with a clutch and stick shift to one with an automatic transmission often results in people trying to press the clutch of the new car and finding it is not there. Over time, people extinguish the unnecessary negative transfer of the "clutch" response. But they can also experience positive transfer of aspects of driving, like keeping an eye on the road and mirrors and using the brakes and steering wheel appropriately. So transfer can have both negative (attempts to find the clutch) and positive (knowing how to drive in general) impacts on people's subsequent behaviors, rather than simply a single good or bad effect.

Other instances of disappointing transfer appear to be the result of people assuming that a new situation is like an old one. They do not recognize that a new situation is something different from those before, and they are unaware of the negative transfer. For example, McNeil (2008) provided children with a novel problem that depended on arithmetic: $7 + 2 + 5 = 7 + \_$. The children transferred their addition skills to the novel problem format by adding up all the digits on both sides of the equation to find a total (i.e., 21). They did not appear to appreciate the novel equivalence format of the problem.

Similarly, Silver (1986) provided students with a word problem on how many buses are needed to transport a group of students. He found that many students concluded that the answer was 3⅓ buses, because they approached the "how many buses do we need" problem by simply dividing the seating capacity of each bus by the number of people going on a trip—evidently forgetting that ⅓ buses are in short supply. Reusser (as cited in Schoenfeld, 1989) presented middle school students with the following problem in the context of other mathematics problems: *There are 26 sheep and 10 goats on a ship. How old is the captain?* Approximately three fourths of the students came up with a numerical answer. As noted elsewhere (Bransford & Stein, 1993), one of us (JB) gave this problem to our child in fifth grade with a strong belief that there would be laughter followed by a statement like "That's ridiculous." Instead, our child looked at the problem, smiled confidently, and gave the answer 36. When asked why that was the answer, he responded (we paraphrase), "Because that's the kind of thing you do in problems like this. This was an easy one, I only had to add."

### Overzealous Transfer

In the examples of negative transfer, it seems safe to say that students gave wrong answers—but wrong answers from whose perspective? In many cases, it is not so clear that a transfer is negative (Lobato, 2003, 2012/this issue). From the vantage point of the students, they may believe they are doing the right thing, and without appropriate feedback they cannot know otherwise. Of particular concern are situations where students transfer skills, knowledge, and routines that are effective for the task at hand but may nevertheless be suboptimal in the long run because they block additional learning. We will call this *overzealous transfer* (OZT)—people transfer solutions that appear to be positive because they are working well enough, but they are nevertheless negative with respect to learning what is new.

Luchins and Luchins's (1959) classic water jug studies of Einstellung (mental set) illustrate problems with OZT. They gave participants three different sizes of jars and asked them to use these to reach a particular target amount of water. To illustrate, imagine a target goal of 25 oz of water and receiving three jars of water that contained 29, 3, and 5 oz of water, respectively. One solution is to find a way to subtract 9 oz from 29. One could pour water from the 29-oz jar into the 3-oz jar three times (emptying it each time). This would yield 20 oz in the big jar. Then one could pour the 5-oz jar into the big jar to reach 25 oz.

Participants in the Luchins's experiment encountered many variations of the water jar problem. A major feature of the experiment was to present people with blocks of problems (known only to the experimenters) that each required a similar set of procedures (e.g., subtracting water from a larger jar, then adding water from a smaller jar). People got better within a block of problems because they developed a helpful mental set for solving a series of related problems. However, the set also caused OZT. Special test problems were inserted throughout the study, which could be solved much more simply than by using the routines the participants had learned. Most participants did not notice the simpler solution and relied on their mental sets. It is noteworthy that the use of the overly complex procedures did not cause errors—people were still able to reach the target numbers. They were just less efficient because they did not let go of their complex mental set to seek a simpler solution.

The Luchins and Luchins (1959) study illustrates three important points about OZT. First, OZT is a type of negative transfer in that people apply old learning in situations where it would be more effective to avoid whole-cloth transfer. Instead, people should selectively transfer some aspects of their knowledge but not others. For example, it was useful for participants to transfer their general understanding of the water jug task across problems, but it was suboptimal to transfer the specific solutions. The second point is that OZT transfer is frequently "good enough" to meet the apparent demands of the task. When there is no mechanism for negative feedback, the transfer of previously successful routines will seem like a positive transfer rather than a negative one. The third point is that OZT can cause people to miss opportunities for new learning. Reliance on old routines that seem to work (at least partially) reduces the need for seeing and adapting to what is new. As we describe next, many instructional routines exacerbate OZT because they provide positive feedback for getting the right answer, without providing negative feedback that the students missed what is new to be learned. In this case, students are not simply "satisficing" (Simon, 1956), but instead they believe they are doing what they are supposed to be doing. In this sense, transfer is overzealous[1] because people are eagerly applying prior routines that they believe will successfully solve the problem at hand.

## INSTRUCTION AND OVERZEALOUS TRANSFER

OZT is not confined to the transfer of concepts or procedures covered in a lesson. OZT can also occur with instructional and learning routines. For instance, in a study of beginning teachers, Grossman (1989) described how one teacher taught *Hamlet* by transferring his own school experience. He loved Shakespeare and learned it in college through a "close reading" of the text, so he taught his students in the same way. This appears to be a case of OZT, and by Grossman's analysis, the high school students learned poorly. In contrast, a second teacher tried to adapt to the needs of his students. He

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[1] We do not mean to use the term *overzealous* to connote an affective component of transfer. For instance, we are not claiming that students are transferring with a strong sense of passion.

began by first asking them to think about the circumstances that might drive them so mad that they would contemplate murdering another human being. Only after students had seriously contemplated the major issues of the play did they begin reading. Rather than transfer in his college experience whole cloth, this teacher attempted to learn what might make an antique story compelling to modern-day students.

OZT can occur in the context of learning, problem solving, and even instructional routines. A common instructional routine is the "tell and practice" (T&P) method. T&P was derived from work on problem solving, which notes that it is not enough to simply provide general statements about problem-solving strategies (Simon, 1980). People must also practice solving problems so they can learn to relate general solutions to specific applications. So teachers and texts typically provide students with sets of "application problems" to solve as homework or after reading a textbook chapter. T&P is an improvement over just telling. But, in practice, there are often shortcomings in implementing this approach.

Richland, Stigler, and Holyoak (2012/this issue) argue that an overuse of T&P in U.S. schools helps explain why they do relatively poorly on international comparisons of math. In reviewing the work of Heibert and Stigler (2004), as well as that of Richland, Zur, and Holyoak (2007), they note that American classrooms and their international peers do not differ greatly in the amount of curricular material designed for active inquiry. The difference is that American instructors rely on a set of T&P routines to teach the material, so there is effectively no inquiry. The teachers overgeneralize an instructional routine.

T&P is what Tyack and Cuban (1995) called a common "grammar of schooling." It is also a common grammar of transfer research. Schwartz, Chase, Oppezzo, and Chin (2011) documented that 75% of studies on the transfer of science, technology, engineering, and mathematics (STEM) content used some form of T&P for both control and treatment conditions, which further indicates the prevalence of T&P routines. Our major concern is that the routines that people transfer can have a tremendous influence over what they will learn and may undermine other manipulations designed to improve the transfer of concepts and skills.

One possible problem with T&P routines is that they can overemphasize efficiency at the expense of discovering new ways of seeing and doing (Bonawitz et al., 2011). The reason is that T&P is a familiar learning routine that focuses on executing what one has been told. Although valuable for exercising an idea or procedure, it can come at the expense of engaging in new learning, such as noticing the unique contextual structures that call for the application of an idea or procedure.

A recent study demonstrates how T&P routines can inadvertently interfere with appreciating key contextual structures (Exp. 2; Schwartz et al., 2011). Eighth-grade students in a T&P treatment were told about some everyday examples of density and the formula that describes them ($d = m/v$). They also received a worked example for how to use the formula to find answers. They then practiced with the application worksheet shown in Figure 1. Their task was to find the density each company uses to ship its clowns to parties. Each company, designated as a row in the worksheet, ships clowns using a constant density of clowns to bus compartments. The worksheet comprises a set of contrasting cases designed to help students notice the ratio structure of density. Each company uses its own ratio so that both instances are proportional. At the same time, different companies use different ratios, so students can see differences defined by ratios rather than simple counts of clowns or buses.

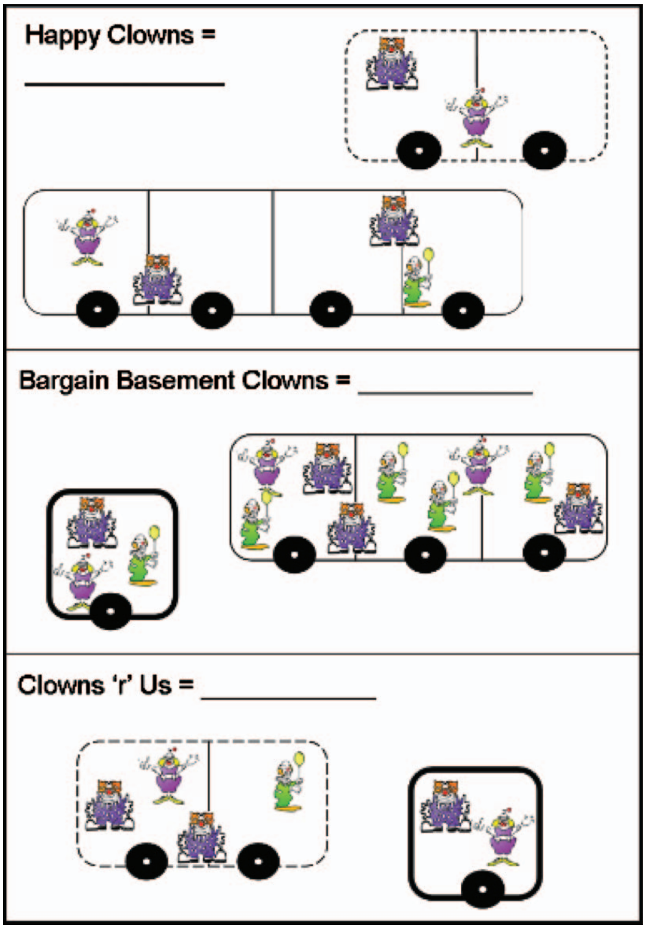


FIGURE 1 Worksheet for learning about density. *Note.* Each row of the worksheet represents a company that uses the same density of clowns per bus compartment. Students in a "tell and practice" condition were told how to compute density and practiced by finding the density used by each company. Would the students learn that density comprises a ratio of mass (clowns) to volume (bus compartments)? From "Practicing Versus Inventing With Contrasting Cases: The Effects of Telling First on Learning and Transfer," by D. L. Schwartz, C. C. Chase, M. A. Oppezzo, & D. B. Chin, 2011, *Journal of Educational Psychology, 103*, p. 761. Copyright 2011 by the American Psychological Association. Reprinted with permission (color figure available online).

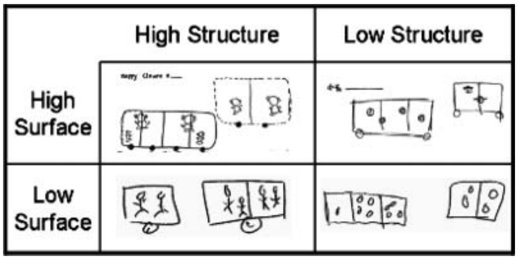


FIGURE 2 Evidence on learning the ratio structure of density. *Note.* Examples of free-recall drawings separated by whether they included the proportionate density structure and whether they included surface features about clowns. From "Practicing Versus Inventing With Contrasting Cases: The Effects of Telling First on Learning and Transfer," by D. L. Schwartz, C. C. Chase, M. A. Oppezzo, & D. B. Chin, 2011, *Journal of Educational Psychology, 103*, p. 765. Copyright 2011 by the American Psychological Association. Reprinted with permission.

Students finished the worksheet in approximately 10 min and were more than 90% accurate at determining the densities. So they were successfully applying the T&P routine. However, the key research question was whether students would also pick up the ratio structure of density. To find out, students were asked to redraw the worksheet a day later from memory.

Figure 2 provides examples of drawings. To receive credit for re-creating the deep ratio structure, students did not have to remember the exact ratios; they just had to produce a pair of proportionate ratios for a given company. Despite being 90% accurate in applying the density formula, they were only 38% accurate in detailing that a given density is comprised of equivalent ratios. (Figure 2 also shows that some students included surface details, such as dotted lines, which was uncorrelated with recreating the deep structure.)

In their zeal to apply the formula, the students turned the physics formula into a division problem. They mapped the variables of the formula (mass and volume) to the features of the cases (clowns and bus cubes), so they could execute the relevant division (mass by volume). They saw the old in the new, namely, a math problem. They did not see the ratio structure of density, which was the important new content. The students were unaware that there was something new to be learned, in part, because they could solve the problems using familiar T&P learning routines. Even when a topic is marked as novel, students can overzealously transfer learning routines that are intended for solidifying skills rather than inducing new patterns. As we describe next, this can have strong consequences for subsequent transfer.

## INSTRUCTIONAL TECHNIQUES FOR BLOCKING OZT

The previous section described the OZT of a common learning routine called T&P. This section shows its consequences for the transfer of concepts. Transferring a suboptimal learning routine *in* to a situation can make transferring the content *out* of the lesson less likely. In this way, the OZT of a learning routine can set the stage for a cycle of transfer failures. In this section, we also describe an instructional technique designed to help students discover what is novel about a problem situation, and we show how it affects transfer.

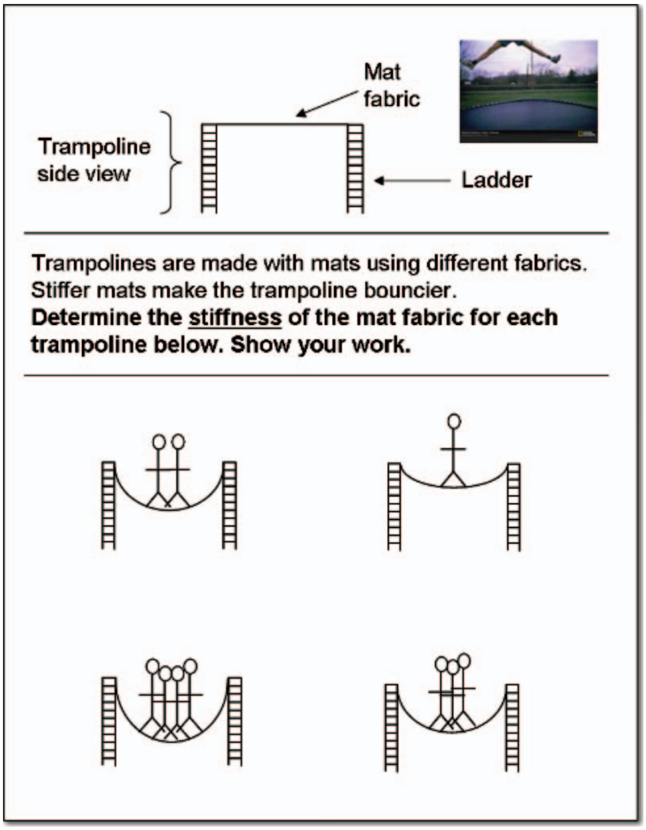
In the previous study, there was a second treatment designed to skirt the OZT of T&P. It used an instructional technique called Inventing with Contrasting Cases (ICC). Students in the ICC condition received exactly the same worksheet (Figure 1), but they were not told about density or its formula beforehand. Instead, they had to invent their own ways to find the "crowdedness" used by each company. They had to invent an index of crowdedness that could be applied to all the companies. The ICC students took about the same amount of time as the T&P students. Despite having little guidance and no feedback, ICC students were quite successful at this task though slightly less accurate than T&P students. About 85% of their crowdedness indices corresponded to the correct density value. Even so, on the next day, 58% of their worksheet redrawings included the proportionate ratio structure of the companies, compared to the 38% in the T&P condition.

These differences had implications for transfer. Over the next few days, the T&P students received a general lecture on the importance of ratio in physics, as in the cases of density, speed, and several other science topics. They then completed three more activities following the same T&P format as the initial lesson; one on density and two on speed (also an extensive ratio, $S = d/t$). Each time the topic of the worksheet was different so students could experience ratio across multiple contents.

The ICC students also received the three worksheets and had to invent an index for each one, as before. It was not until after these inventing activities that they finally heard the lecture that explained ratio and the canonical formulas. Both groups then solved a series of standard word problems on density and speed for about 15 min.

A week after completing the lessons, the students in both conditions received a pair of posttests. One posttest asked them to solve computational and qualitative word problems about density and speed. The two conditions achieved the same level of accuracy ($\sim$65%), which indicates that ICC did not come at the expense of learning the standard solutions relative to the T&P treatment. The second posttest held the transfer problem. Figure 3 shows that students had to describe the stiffness of different trampoline fabrics (i.e., the spring constant). The question was whether students would use a ratio to describe the stiffness of the fabric—number of people by the stretch of the fabric (number of rungs).

By this time, participants in the T&P condition had received a series of analogies that all involved the structure of ratio, they were told the general principal that connected the examples, and they successfully followed a set of worked



Trampolines are made with mats using different fabrics. Stiffer mats make the trampoline bouncier. **Determine the <u>stiffness</u> of the mat fabric for each trampoline below. Show your work.**

FIGURE 3 A problem used to test the transfer of the ratio concept. *Note.* The question was whether students would use a ratio of people by stretch distance to describe the fabrics for each trampoline. From "Practicing Versus Inventing With Contrasting Cases: The Effects of Telling First on Learning and Transfer," by D. L. Schwartz, C. C. Chase, M. A. Oppezzo, & D. B. Chin, 2011, *Journal of Educational Psychology, 103*, p. 765. Copyright 2011 by the American Psychological Association. Reprinted with permission (color figure available online).

examples to prepare them for the worksheets on a variety of topics. All of these are known to support transfer (e.g., Brown & Kane, 1988; Gick & Holyoak, 1983; Pass & Van Merrienboer, 1994). Nevertheless, the zeal to follow the T&P learning routine trumped the effectiveness of these techniques, and this had consequences for the trampoline transfer problem. About 23% of the T&P answers used a ratio structure to describe the stiffness of the trampoline fabrics, with most of the answers simply counting the number of people or the number of rungs, but not both. In contrast, the ICC students correctly used a ratio 51% of the time. The study also found that the low-achieving ICC students (based on class grades) outperformed the high-achieving T&P students at transfer (41% vs. 33%, respectively).

We interpret the poor performance of the T&P group as a result of OZT. They practiced what they had been told when using the worksheets, which makes sense, given that it was good enough to achieve the right answers on the worksheets. However, this success had the hidden consequence that the students did not learn what was new, namely, the ratio structure of many physical phenomena. As a result, they did not transfer because they had never learned to recognize the applicability conditions for the use of ratio.

Other experiments and transfer tasks replicated these findings and demonstrated strong benefits of ICC over T&P, even when the ICC students never heard a lecture on ratio before the transfer problem. It is important to note that the ICC students were not left to their own devices to come up with a new learning routine. The worksheets were carefully designed as contrasting cases that highlighted the ratio structures, and students were specifically told to invent a quantitative index to characterize the cases. Across all the inventing worksheets, ICC students got 85% of the answers correct (T&P students were at 92%). This differs from prior studies that have found an advantage for T&P instruction compared to unscaffolded exploration (Klahr & Nigam, 2004; Tuovinen & Sweller, 1999). Many students do not have good learning routines for exploration, given that American schools use a heavy diet of T&P. It makes sense that without routines for organizing their learning, students would flounder in free-exploration conditions compared to the strong guidance of T&P. The preceding ICC lessons were one way to provide students with a tractable learning routine to help them adapt to what was new (to them) about the physical phenomenon. It effectively stopped students from overzealously transferring in suboptimal learning routines while providing an alternative learning approach.[2]

Additional studies have also shown benefits of asking students to invent their own descriptions of a set of well-organized data compared to T&P. Schwartz and Bransford (1998) demonstrated the benefits of invention for transfer with college students learning principles of cognitive psychology. Schwartz and Martin (2004) made a similar demonstration with high school students learning statistics. Kapur (2008) found that withholding answers improves the depth of learning and transfer, even when students often fail to generate the correct solutions. Parker et al. (2011) redesigned an American Government, Advanced Placement (AP) course, so that it was organized around a set of challenges where students engaged in relevant activities (e.g., participating in a mock trial) prior to receiving detailed lectures and readings. It inverted the usual learning routine, so that "telling" came after, rather than before, substantive problem solving. Students who took this version of the AP course scored as well as, or better than, control groups that used a traditional

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[2] A reasonable question is whether it would work to have students complete T&P and then invent afterward. Although it remains to be tested, our speculation is that they would just apply the formulas they had been taught without finding the deep structure of the ratios. It would be difficult for students to forget what they had just learned to only come up with the exact same answer through inventing. If the problems were masked so that students did not know they were finding density or speed, then they would be inventing again rather than reusing what they already knew, and we would expect them to show the benefits of avoiding the zealous application of division.

AP course (highly memory oriented), and they did better on a "complex scenario test" where students were asked to solve novel problems. Similar kinds of "inquiry first" instruction have yielded more effective and flexible transfer in middle school science (Shutt, Vye, & Bransford, 2011). Ideally, there would be more studies to report, but as mentioned earlier, most studies of transfer have used a "tell-first" approach for all the conditions.

Results like these led Schwartz, Bransford, and Sears (2005) to hypothesize that flexible transfer could be enhanced through the use of well-designed innovation activities that help students first recognize applicability conditions before learning the efficient solutions through T&P. The innovation activities, which can seem inefficient at first glance, speed up the subsequent acquisition of the efficient solution, once delivered, because students understand what the solutions need to accomplish. In addition, starting with an innovation activity blocks the natural tendency toward an OZT that stops students from noticing what is new. This does not mean that all lessons should begin with guided-discovery activities. For example, improving automaticity depends on practice that emphasizes speed and accuracy. Guided-discovery activities are most appropriate when the goal is to help students see what is new (for them).

## PROFESSIONALS WITH METHODS FOR AVOIDING OZT

People need efficient schemas and routines that enable them to handle recurrent situations quickly and effectively. When it is possible to anticipate a stable future, routine expertise is appropriate. For instance, in the foreseeable future, English words will be read left-to-right, top-to-bottom; will be comprised of letters; and will have spaces in between. For decoding words, we want to put students on a trajectory of routine expertise, so they can take advantage of the stability of words with high efficiency. For other topics, there is less of a guarantee that the future will resemble the past. When learning in school, topics change from week to week, and many workplace demands change with the times. In these cases, we want to help people rely on their past efficiencies but also go beyond those efficiencies so they can better learn what is new. For schools, it seems possible to design instruction that avoids the perils of OZT and helps students balance important routines with the needs for new learning.

A different challenge involves preparing people to avoid OZT once instruction is no longer present. Are there ways to prepare people for the transfer of learning routines that, despite being routines, manage to block OZT?

Professionals provide a useful test case. They have accumulated a body of knowledge that enables them to complete their work effectively, so they do not need to incur the inefficiencies of learning from each new instance. This may lead them to OZT, because they might see each new instance as an old one. At the same time, they may have learned routines to resist overassimilation, so they can seek what is novel rather than always use prepackaged solutions.

Miller (1978), who studied information designers, provided a useful example. He found that some designers were "virtuosos" who actively sought contextual information to adapt their designs to specific client needs. These designers fit the description of adaptive experts, who seek to understand the variability of new contexts (Hatano & Inagaki, 1986). However, he also found designers who were "artisans." They used off-the-shelf solutions to satisfy their clients. These designers fit the description of routine experts, who rely on the efficiencies of prior knowledge to get the job done. We are especially interested in examples of adaptive experts.

One example comes from Wineburg's (1991) comparison of college students and professional historians. Working individually, they each received a set of source documents and had to explain what happened at the Battle of Lexington. The historians were not experts in American history, but they were professional historians who had specific approaches to avoid OZT. They did not assume that the words in each document were true, but rather, they attempted to better understand the intents of the documents' authors and the historical context in which they were written. In contrast, college students did not attempt to explore and understand the perspective behind each data source; they tried to understand the documents based on their own experiences. From the vantage of most schooling practices, the college students demonstrated appropriate transfer. They tried to make sense of the facts in the texts by connecting them to prior knowledge (e.g., Anderson & Pearson, 1984; Bransford & Johnson; 1972). In contrast, the experts had learned a set of approaches that enabled them to avoid the OZT of this familiar reading routine.

Using a similar research design, Atman, Chimka, Bursic, and Nachtmann (1999) studied engineering students and professional engineers. Participants were asked to design a playground, given a set of initial specifications. Compared to students, the professional engineers were much more likely to ask for additional information from stakeholders rather than assume they fully understood the design context, and seniors in engineering were more likely to ask relevant questions than were juniors, who in turn asked more than sophomores did. So, like the professional historians, professional engineers seek out new information so they can develop a better understanding and formulation of the problem context.

In addition to seeking new information rather than assuming they know enough to get the job done, Martin and Schwartz (2009) demonstrated that adaptive experts also work to organize that information, even when it is not strictly necessary to get the job done. They looked at graduate students—early-stage experts—in STEM domains. They compared them to undergraduates solving a set of novel diagnosis problems. On sheets of paper, the students received cases that described prior patients, their symptoms, and their diagnoses. Their task was to use these cases to help order tests and make diagnoses for new simulated patients on a nearby computer. The undergraduates immediately turned to the computer. For each new patient that appeared on the screen, they would search through the sheets of paper to determine what test to order and, based on the test results, they would sift through the papers again to decide the next test and/or diagnoses. This was sufficient to get by, and the undergraduates' ultimate diagnoses were excellent. In contrast, by the time the undergraduate students were nearly done, the graduate students had not diagnosed a single patient!

Every single graduate student spent approximately the first 10 min creating a representation of the original cases, for example, by making a tree or matrix of the symptoms and diseases. When the graduate students finally turned to the computer to start diagnosing, they never looked back to the sheets. So, whereas the undergraduates handled each case as it arose, which was sufficient to complete the task at hand, the graduate students gave up short-term efficiency to create a general (visual) solution that could handle any case. The graduate students had the same diagnostic accuracy as the undergraduates, but they were better at ordering the minimal number of tests to make a diagnosis.

We surmise that the graduate students had learned the value of considering the long-term nature of tasks when it comes to handling data and that this prompted them to find a general solution that would ensure long-term success across many problems. We do not know if the graduate students were explicitly taught to create data visualizations, but we do know that instruction can be enhanced so that students transfer the idea of creating "smart tools" that can handle a range of contextual variation (Schwartz, 1993; Zech et al., 1998).

In each of the preceding examples, the experts had domain-specific routines for avoiding OZT. The graduate students had learned to look for general solutions when it comes to data analysis, the historians had learned to contextualize documents to their sources, and engineers had learned to ask for more information from clients in a design task. The routines were tailored to recurrent professional situations, where OZT could be problematic. A valuable contribution to professional education would be to discover and inculcate profession- or discipline-specific ways to avoid OZT.

## LEARNING ROUTINES FOR AVOIDING OZT

Learning routines that can help overcome OZT exhibit a strong focus on active understanding of new and variable contexts while seeking explanations and solutions that generalize across the stable components. Often times, these learning routines depend on bypassing solutions that are good enough, yet are not optimally sensitive to context.

Even so, the development of any new learning routine runs the risk of OZT. For instance, teachers and students might overgeneralize guided-discovery activities to situations where telling first might be more appropriate. Ideally, people would know the conditions under which one learning routine is more optimal than another, and when it is important to learn rather than just perform. Perhaps it is possible for people to develop a meta-routine for deciding among different learning routines across the range of contexts and outcomes that one might conceivably anticipate in an ever-changing future. Unfortunately, we know of no examples of successful metastrategies for selecting among learning routines.

However, there is a promising general solution for helping overcome OZT: Actively seek feedback. Prior to developing a deep understanding of an endeavor and its context, people do not have internal models that enable them to self-monitor whether they are overassimilating. Without support for noticing, people can miss many features of their everyday experiences (e.g., Feuerstein, Feuerstein, & Falk, 2010; O'Mahony et al., 2012), and what they do notice can be limited in its scope. Feedback provides an important source of information, because it can alert learners that their current routines and knowledge are suboptimal. Educators often provide feedback for learning, and this is very important (e.g., Black & Williams, 1998). However, people also need to develop learning routines to seek feedback rather than wait for it, or worse, avoid it (Chase, 2011).

As an illustration, good designers have a strong tradition of being client and stakeholder centered (Bransford et al., 2011; Nelson & Stolterman, 2003). Their interactive learning routines lead them to continually seek feedback from clients as well as from those who will be impacted by their designs (Atman et al., 1999). This can help block the kinds of OZT that fail to take into account new features, needs, and opportunities that would be missed if they simply used their previously acquired assumptions of what a good solution would be. Several design schools now use client- and stakeholder-centered design with their students, in the hopes that they develop feedback-driven learning routines (e.g., Olin College of Engineering and Stanford Design Institute).

Outside of design, another example of feedback-seeking routines is found in Problem-Based Case Learning (PBCL), an instructional approach that is being developed by a group of community college leaders (http://www.makinglearningreal.org). PBCL involves teachers and students working with local small businesses to help everyone learn from one another (Johnson & Loring, 2012). PBCL actively connects community college instructors and students with small business owners and heads of other programs that exist in their local communities. In addition to creating a need to know and a reason to get it right, PBCL maintains constant interactions among collaborators and hence helps students and instructors realize when their proposed solutions represent negative or positive transfer through feedback from client and stakeholder perspectives. We suspect that these types of PBCL routines will transfer, given sufficient experiences. For example, students in PBCL should develop the kinds of information-seeking propensities and skills demonstrated in the previously discussed studies of expert designers conducted by Atman et al. (1999).

Is there a way that approaches like PBCL could be brought to K-12 classrooms, especially when younger students are less able to produce designs that would be embraced by clients? With some adaptation to the basic model, it seems possible. For example, in American Government courses, students can engage in simulations of political decision making where students play the role of different constituents (Parker et al., 2011). To ensure that students can move beyond the assumptions they bring to their roles, experts can visit the classroom to provide "pushback." In addition, new technologies and games provide possibilities for creating rich feedback in a variety of contexts including social studies and political science (e.g., http://www.icivics.org; http://www.legsim.org). Future research should explore novel ways of helping students learn to seek feedback, plus explore the bigger question of whether seeking feedback can become a balanced routine that transfers well.

## SUMMARY

Many people have proposed that transfer is rare (e.g., Detterman, 1993; Lave, 1988). From this vantage, the question is whether it is possible to improve rates of positive transfer so that people can efficiently reuse prior learning in otherwise novel situations. From another perspective, transfer is ubiquitous. There is no situation, no matter how novel, where people do not transfer in prior experiences to make some sense of that situation. From this vantage, the challenge is how to help people avoid negative transfer, so they can reduce the hold of prior knowledge to more effectively learn what is new and adapt. Both perspectives are correct. The overarching question for transfer should ask how people can strike a balance between (a) the efficiencies of seeing the "old in the new" and reusing what they know and (b) the adaptive learning that comes from seeing the "new in the old" and exploring learning opportunities that may exist.

The tensions of positive and negative transfer apply to organizational learning as well as individual learning. For example, the organizational theorists Levinthal and March (1993) described exploitation and exploration. Exploitation is "the use and development of things already known," whereas exploration is "the pursuit of knowledge, of things that may come to be known" (p. 105). Their focus involves the strategic management of corporations and the kinds of organizational supports and routines put in place to balance efficiency and innovation (see also Bransford et al., 2012). In this sense, individual attitudes and learning strategies are affected by the organizational structures and goals of the company.

For both the organization and the individuals, issues of OZT are pervasive because it is often efficient to attempt to exploit previously successful routines but, in the process, overlook opportunities to learn that may yield even more successful ways of proceeding. The analogy between strategic management and individual learners reacting to an everyday world should not be taken too far. But mapping from the corporate world to individuals can help highlight issues that individuals face, especially regarding OZT.

The Boeing Company's switch from aluminum planes to composite planes provides a useful example for drawing out the mappings and the differences. The company had expertise and infrastructure in the development of aluminum planes, which it had successfully exploited. Nevertheless, it made a decision to explore and eventually pursue a plane made of composite materials (e.g., see Stevens & Richey, 2011). This caused some short-term losses in efficiency (what Fullan, 2001, called "implementation dips"), as the company had to adapt along a number of dimensions, including how to teach the employees to work with composites instead of aluminum (Lawton et al., 2012; O'Mahony et al., 2012).

One mapping involves feedback loops that inform actions and decisions. Boeing's decision to invest in how to make a fundamentally new plane was based on strong metrics about a number of issues (customer demand, the design of new materials) that signaled the need to break from the past. In contrast, many school practices do not provide the kinds of feedback opportunities that are important for adaptation—especially in our fast-changing environment. For example, many schools do not gather sufficient feedback about the performance of policymakers, teachers, students, and communities—the lack of which allows individual and institutional learning routines to become entrenched.

For individuals, there often is not a set of strong routines in place for regularly seeking feedback. Hence it can be difficult to recognize that one is overrelying on prior knowledge based on what has worked in the past. From the perspective of the individual, when feedback is not naturally forthcoming, transfer can look positive when it may be negative. The importance of feedback, especially formative feedback that offers opportunities for new learning, is well known (e.g., Black & Williams, 1998; NRC, 2001; Thorndike, 1904). This brings up the concern that even when feedback is provided, it can be misleading (Bransford & Schwartz, 1999). For example, students may receive positive feedback for correct answers, but they may still not notice what is new in a lesson.

A particularly important issue is that instruction often does not prepare students to seek feedback once they leave the orchestrated lessons and tests of school. Without learning routines for seeking feedback, it is less likely that they will receive signals for when they should adapt and learn. We described several promising approaches for helping people learn to seek feedback (e.g., working with actual clients as in many design schools), but this is an area that requires more research.

Another mapping between corporations and individuals involves the challenge of letting go of familiar routines and knowledge that appear to be working well enough. In the Boeing case, the decision to engage in composite planes was a calculated and considered risk that factored in the likely short-term losses and costs of retooling against the projected benefits. When learners give up well-known ways of accomplishing immediate goals to pursue novelty, they also put themselves at risk. For instance, they may actually be in a situation where it would have been better to stick with the tried and true. Moreover, people must be able to handle the ambiguity that often accompanies innovation and adaptation. They must believe they can be efficacious in learning something new (Bandura, 1997) and that they are capable of changing their ways of thinking and doing (Dweck, 2000; Nolen, Ward, & Horn, 2011). Another critical factor in adapting to new situations is having the courage to persist despite initial failures (Chase, 2011). Letting go of old routines requires a disposition that can tolerate the potential perils of the new and unknown.

In sum, the literature on transfer has predominantly studied positive transfer on the assumption that it is the most efficient and rational behavior. When we add OZT to the mix, the assumption changes, so the question becomes how people strike a balance between positive transfer and overgeneralizations that block new learning. Finding the appropriate balance is difficult and typically goes beyond a learner's possible rational analysis of the available information. As such, it brings a host of new issues that range from seeking more information to developing dispositions for handling ambiguity and failure. Research on transfer would benefit by expanding its boundaries, so it is not just about how to help people get the right answer but also about how to help people to continue learning.

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