Transfer of Learning:

Issues and Research Agenda

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Transfer of Learning: Issues and Research Agenda *†

Report of a Workshop
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† This report is dedicated to the memory of Rodney R. Cocking, who was instrumental in planning this workshop but who suffered a tragic death a month prior to the workshop.

Transfer of Learning: Issues and Research Agenda

On March 21-22, 2002, a workshop on transfer of knowledge was held at the National Science Foundation in Arlington, Virginia. The workshop was funded by the NSF and organized by the late Rodney Cocking from NSF and by Jose Mestre from the University of Massachusetts. For one and one-half days 12 NSF program officers and 22 participants, representing diverse fields such as developmental, social and cognitive psychology, educational media/technology, cognitive science, and research into teaching and learning, met both to discuss past and present issues of transfer as it pertains to education and to generate a research agenda for the future. The National Science Foundation is planning to fund several Science of Learning Centers (SLCs) in the near future; it is hoped that the research agenda contained herein will be useful and informative for future research planned in the SLCs.

We begin with a broad introduction of transfer of knowledge, discussing why it is both central and timely to the country's educational mission in science, mathematics and engineering. Next the background leading up to the workshop is presented, including the governing charge and organizing themes. We then present the research agenda that resulted from the participant's deliberations, and conclude with final remarks to place the research agenda in perspective. An appendix contains a complete participant list and the agenda followed in the workshop.

Introduction

We define transfer of learning (hereafter transfer) broadly to mean the ability to apply knowledge or procedures learned in one context to new contexts. A distinction is commonly made between near and far transfer. The former consists of transfer from initial learning that is situated in a given setting to ones that are closely related. Far transfer refers both to the ability to use what was learned in one setting to a different one as well as the ability to solve novel problems that share a common structure with the knowledge initially acquired. We note that there is an emerging third way to talk about transfer, one that meets a criterion of generativity. The idea here is that learners can, on their own, come up with novel instances or solutions. Some kinds of expertise involve generativity. So do our common ability to talk, almost always using novel utterances in everyday conversations; learnings that constitute conceptual changes or reorganizations of knowledge as a function of instruction; and changes that can be related to advances in cognitive development.

We will not attempt an extensive review of the current transfer research literature; we refer the interested reader to an excellent overview of the topic in chapter 3 of the National Research Council report, ***How People Learn*** (Bransford, Brown, & Cocking, 1999) as well to Brown and Campione (1998), and Brown, Bransford, Ferrara & Campione, (1983); for topics related to generativity see Carey and Spelke (1994) and Gelman and Williams (1998). An excellent article by Barnett and Ceci (2002) provides a literature review of the salient research on transfer, a taxonomy that can help organize the field, and directions for future study. Rather, we develop the case that a research agenda for transfer is both important and timely. It is important because of the pivotal role that transfer plays in education. The application of knowledge taught through schooling or training to contexts other than those in which the knowledge was initially learned is among the most important goals in education (Halpern, 1998). Yet, we are only beginning to see how to do the relevant research. A research agenda is timely because we now know much about human cognition (of which transfer is a subset) and are in a position to consider ways of extending this body of work to include research that is directly aimed at finding ways to improve teaching and learning. We now expand on these two points.

A major, but often tacit, assumption in education is that the knowledge that students learn in school will transfer to situations and problems encountered outside of school. Indeed much of our investment in education is justified in terms of preparing students for future learning so that they may become productive members in a society where workplace needs and demands are in constant flux. Clearly there is ample evidence for the usefulness of education in an advanced service-based society. In a variety of ways we know that schools do teach many the basic skills of reading, writing and reasoning. Witness the extent to which employers use educational level as one aspect of a job descriptions. Still, many students cannot meet these requirements, a fact that hampers their ability to advance in the workplace. There is also evidence that schooling improves IQ, as well as increases income (Ceci & Williams, 1997). Yet, despite these tacit assumptions, our educational system is inefficient at teaching in ways that promote transfer. Whether measured by standardized tests, or by laboratory studies of transfer, it is evident that transfer of knowledge is elusive.

Some classic studies of analogical transfer illustrate that transfer of relevant knowledge from one situation to a second where the task is isomorphic (that is shares the same structure), but the context changes, is not common (Gick & Holyoak, 1980; Hayes & Simon, 1977; Reed, Dempster, & Ettinger, 1985; Reed, Ernst, & Banerji, 1974). Only after receiving hints pointing out that two situations are isomorphic are students able to transfer relevant knowledge. More recently Blanchette and Dunbar (2002) have found that, although students can spontaneously draw analogical inferences from one domain to another, they do not make enough inferences to support a fully fledged transfer from one domain to another. If, as these studies suggest, the ability to apply knowledge flexibly is so context-bound then an important question for education is how to structure instruction to ensure transfer, short of the impossible task of covering in detail all the relevant contexts in which the knowledge being taught could be applied. What, then, is known about successful transfer and what does it depend on?

Research suggests that several factors affect transfer. First, some initial acquisition of knowledge is necessary for transfer (Brown, et al., 1983; Carey & Smith, 1993; Chi, 2000). Although this seems obvious, it is noteworthy that many failures to produce transfer have resulted from inadequate opportunities for students to learn effectively in the first place (e.g., see discussions by Brown, 1990; Klahr & Carver, 1988; Littlefield, Delclos, Lever, Clayton, Bransford, & Franks, 1988). Attention to initial learning is very important for transfer, especially when measures of transfer are used to evaluate the degree to which educational interventions are or are not "effective." Whereas rote learning does not tend to facilitate transfer, learning with understanding does (Bransford, Stein, Vye, Franks, Auble, Mezynski, & Perfetto, 1983; Mandler & Orlich, 1993; see also literature review in Barnett & Ceci, 2002). Thus, attempts to learn too many topics too quickly may hamper transfer since the learner may simply be memorizing isolated facts with little opportunity to organize the learned material in any meaningful fashion or to link it to related knowledge. Although previous learning can enhance transfer, it can also obstruct it (Bransford, et al., 1999; Gelman & Lucariello, 2002). For example, new learning may not proceed rapidly if knowledge that the learner possesses that is relevant to the new learning remains inactivated; on the other hand, when tasks share cognitive elements, transfer is facilitated (Glaser, 1994; Singley & Anderson, 1989). This is true even for young children (Brown & Kane, 1988).

Context also plays a pivotal role in transfer. If the knowledge learned is too tightly bound to the context in which it was learned, transfer to superficially different contexts will be reduced significantly (Bjork & Richardson-Klavhen, 1989; Carraher, 1986; Eich, 1985; Lave, 1988; Mestre, 2002; Saxe, 1989). For example, students who learn to solve arithmetic progression problems can transfer the method they learned to solve similar physics problems involving velocity and distance, but students who learn to solve the physics problems first are unable to transfer the method to solve isomorphic arithmetic progression problems (Bassok & Holyoak, 1989). The transfer from physics to arithmetic was apparently blocked by embedding the physics equations within that specific context which then precluded students from seeing their applicability to another context. These findings also suggest that because students had more general knowledge about arithmetic/algebra, those who learned to solve the problems within a math context first were able to screen out the content-specific details of the problem-solving procedures, whereas those who learned to solve the physics problems first appear to attribute the underlying physics context as crucial to the application of the problem-solving procedures, and hence were unable to apply those procedures to a math context. Further, the context within which quantities/variables in a problem are presented affects transfer, as a study by Bassok (1990) demonstrated; students exhibited spontaneous transfer from problems involving speed (meters per second) to problems involving price rate measured in dollars per minute, but not to problems involving salary rate measured in dollars per year. It appears that dollars per minute was interpreted by students as a continuous rate similar to meters per second, but dollars per year was interpreted more like a discrete quantity rather than a rate, and hence the lack of transfer.

Apart from factors that affect transfer, the issue of how to measure transfer has attracted recent attention (Bransford & Schwartz, 1999). These researchers observe that most measures of transfer use a paradigm of “sequestered problem solving” (SPS) in which people complete tasks isolated from additional knowledge resources that are typically available in non-laboratory settings. They question whether these SPS assessments have blinded the field to the role of transfer in facilitating subsequent learning, for example, when progressing from one mathematics class to the next. What was learned on day one in the math class may not produce strong transfer when tested in an SPS manner on day two. However, day one experiences may facilitate students’ abilities to learn new information on day two. An emphasis on facilitating learning is the hallmark of an approach to transfer that focuses on “preparation for future learning” (PFL) rather than only on SPS transfer per se.

Overall, Bransford & Schwartz (1999) note that SPS measures of people’s abilities to retrieve spontaneously problem solving procedures and relevant facts in a new context is a useful measure of well-developed expertise, but it is often too blunt an instrument to measure the role of transfer for novices who know less about a subject area. Having a less blunt measure of transfer is important for educators, because transfer is one of the major criteria used to assess the relative effectiveness of different instructional procedures. For example, Schwartz & Bransford (1998) found that students who received different instructional treatments looked similar on standard knowledge assessments. However, when given an opportunity to learn from additional resources, one method of instruction looked far superior. If only SPS measures of transfer had been used, very different conclusions about instructional effectiveness would have been reached.

PFL measures of transfer may also help the field differentiate good versus poor ways to “teach to the test.” Many ways of “teaching to the test” may prepare students to do well on SPS “near transfer” problems yet fail to prepare them effectively for future learning. The development of new models of transfer-minded instruction and assessments that target PFL appears to be a fruitful focus for further research.

In summary, research suggests that transfer is enhanced when the learner abstracts the deep principles underlying the knowledge being learned, and that abstraction is facilitated by opportunities to experience concepts and principles in multiple contexts. People's prior knowledge and experience in a domain affects their subsequent transfer, although sometimes the effect is initially negative because previously learned concepts and routines must be changed to deal with new settings (e.g. Barnett & Ceci, 2002; Bransford, et al., 1999; Bransford & Schwartz, 1999; Hartnett & Gelman, 1998; Singley & Anderson, 1989). In educational settings, this is frequently referred to as "the implementation dip" or the "J curve effect" (e.g., Fullan, 2001).

Despite our rapidly growing knowledge about transfer and factors that facilitate it, we know little about how to construct classroom environments for learning at levels that foster transfer. The question of how to formulate research questions so as to study in-class learning and transfer is just in its infancy (e.g., Silva & Kellman, 1999; Stigler & Fernandez, 1995). That is, how this research gets translated into better schooling remains to be investigated. There are some obvious obstacles to applying research findings in instructional settings to enhance transfer, such as the intransigence of the "teach-as-you-were-taught" cycle and the fact that there is often a long lag from when research findings are known to when they find their way to pre-service teacher education programs. But perhaps more importantly, there is also research evidence suggesting that in order to facilitate transfer we may need to structure instruction in ways that are counter-intuitive to both teacher and learner—counter-intuitive in that instructional changes suggested by research may fly in the face of tradition and common sense.

Examples of this emerge in training motor skills where it has been known for some time that random practice is superior to blocked practice (Kerr & Booth, 1978; Shea & Morgan, 1979).[*] Yet, if participants are asked their perception as to which method is better for their own learning, they believe it to be blocked practice rather than random practice, a perception that is contrary to measured performance (Baddeley & Longman, 1978; Nitsch, 1977; Simon & Bjork, 2001). This erroneous perception may be shaped by tradition and our past educational experiences since blocked practice is how schooling is structured. That is, school curricula are structured in a sequenced (blocked) fashion where students learn topic A, then move to topic B, then C, etc.; yet, when students have to deal with all these topics simultaneously (e.g. at the end of the course or after the course is over) they falter unless they have had some random practice.

In more cognitive tasks such as learning from textual material, research indicates that perceived efficiency or fluency may not be what is best for the type of learning that promotes problem solving and inference. For example, students given an outline of textual material prior to reading it perform inference and problem solving tasks better if the outline does not follow exactly the same organization as the text (Mannes & Kintsch, 1987). In addition, evidence also suggests that students possessing high knowledge in a domain do better at inference and problem solving after reading a passage related to that domain if the passage is sparse, requiring significant active processing of its meaning; this is in contrast to the poorer performance of students when the passage was much more complete, requiring less processing of its deep meaning (McNamara, Kintsch, Songer & Kintsch, 1996). Furthermore, research by Dunbar and colleagues has revealed that when students are required to process information for meaning there is a large influence on transfer. They found that students can use underlying structural information when they are asked to generate analogies, but use superficial information when asked to recall similar information (Dunbar, 2001; Blanchette & Dunbar, 2000). These findings are consistent with a large body of research which shows that "effort after meaning" (or "generative processing") facilitates learning (e.g., Auble & Franks, 1978; Bartlett, 1932; Slamecka & Graf, 1978; Wittrock, 1990).

Another example of potentially "counter intuitive" approaches to instruction consists of beginning lessons by first having students generate their own, perhaps incorrect, thoughts about phenomena versus simply telling students the correct answers. One reason for advantages of the "generate first" approach is that it provides an opportunity for students to contrast their own thinking with that of others, including experts in an area. This sets the stage for appreciating the critical features of the new information that is presented to them. For example, Schwartz and Moore (1998) find that students are better prepared to appreciate the formula for variance if they first receive opportunities to generate their own (usually incorrect) ideas as they differentiate the elements of "spread" for which the formula accounts. To help differentiate these elements, students are shown an initial pair of distributions, say {2, 4, 6, 8, 10} and {4, 5, 6, 7, 8}. After pointing out to students that one number—the average—can be used to capture the similarity between these two sets, students are then asked to come up with a method for determining a single number for each set that could capture what is different (i.e., the variance). After they invent their own methods (often a range formula) they receive a new pair of distributions, say {2, 4, 6, 8, 10} and {2, 10} and determine whether their formula works for these sets as well, and if not to fix their formula. This continues for several cycles where students generate a formula and then try to apply it to new distributions that highlight new quantitative properties (like sample size and density). At the end of these exercises, students may be shown the formula for variance used by experts.

The findings of Schwartz and Moore (1998) suggest that even though the students generated faulty formulas, these experiences helped students become aware of the quantitative properties of distributions that a formula should take into account. This set the stage for noticing critical features of experts' formulas; for example, that it yields a smaller number for smaller variances; that it elegantly solves the problem of set size, and so forth. As a consequence, students in the "generate first" group were much better able to appreciate the strengths and weaknesses of different non-standard formulas for capturing variance (e.g., a formula that summed the deviations from the median instead of the mean). In contrast, students who had been directly taught the standard formula (with no previous attempts to generate their own thoughts) simply declared that the non-standard formulas were "wrong." They were not as prepared as the other students to learn about the expert formula. In Broudy's terms (1977) they had a less well-differentiated "field" of knowledge for appreciating the nuances of the expert formula.

What these previous examples suggest about effective learning does not reflect societal values, or even what we consider efficient in education. In school students study a topic until reaching some level of mastery and then move on to the next topic, whereas research suggests that transfer is improved by visiting the topics often rather than once intensely. We hold in high esteem and reward instructors who make clear, lucid, logical presentations that are totally understandable and easy to follow by the learner, yet research suggests that a) passively listening to an argument lacks the mental engagement necessary to promote deep learning, and b) some initial explorations on the part of the student when learning a new topic, even if those explorations generate erroneous notions, can be profitable in terms of eventually generating a deeper understanding of the topic.

Suggesting that the research cited earlier indicates that we should make textbooks and lectures more incoherent is clearly an overstatement. On the other hand, some middle ground is worthy of investigation. Perhaps clarity and coherence is most efficient at helping learners achieve some core knowledge, but after reaching some threshold knowledge it may serve the learner better to rely less on instruction and more on her/his own mental efforts to make sense and distill the knowledge into a form useful for future use.

Background

The workshop was organized around the following three themes:

1. **Context dependence of transfer**. The acquisition of knowledge or a skill does not ensure that the knowledge or skill will be appropriately (or inappropriately) applied to relevant situations. What do we need to know about the contexts of learning or application of learning in order to facilitate transfer?

2. **Conditions for transfer**. What are the conditions that affect the appropriate (or inappropriate) application of knowledge or skill. What do we need to know about the contexts of learning, or application of learning, in order to facilitate transfer?

3. **Metacognitive issues for transfer.** Metacognitive research indicates that a significant part of effective learning is to be aware of, and in control of, one's own learning. What research base is needed to promote reflective learning? What are the implications for classroom practice?

Workshop participants were divided into three groups, with each group working on one of the themes above. Participants were given the governing charge for the workshop at the opening plenary, namely that by the end of the workshop, each group should have formed answers to three organizing questions for each of the three themes: 1) What are the primary issues?, 2) What is the research knowledge base? (What do we know?) and 3) What do we need to find out? (How can we learn more?) A chair and a co-chair were named for each group to keep the group on task and to capture the consensus of the discussions. More details concerning the agenda and charge are provided in the Appendix.

Outcome of Workshop: Research Agenda

The three sub-sections below are the reports from the co-chairs of the breakout groups that discussed the three themes outlined in the previous section. The three reports are included here in largely the same form as they were submitted, and hence the format and style of each is unique. To have "sanitized" each report into a consistent format would have not captured the unique flavor of what transpired in each group. It is interesting to note common threads running across the three reports below, such as whether or not current assessment practices are structured to measure, or even promote, far transfer, and how instruction might be structured to promote far transfer as opposed to doing well on mandated tests.