Fostering Transfer of Knowledge in Education Settings

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How do students use what they learn in one context and apply it to another? The issue of transfer of learning is one of the most central topics in both cognitive science and education. This symposium brings together cognitive scientists, developmental psychologists, and education researchers who will discuss the question of transfer in the lab and in the real-world context of education. This set of talks examines transfer across learning contexts (computer simulation or classroom), across ages from preschool to college, and across content domains (science and math). The symposium will provide valuable insight as to what conditions facilitate transfer and what conditions impede transfer. *Elizabeth Albro* is the moderator for this panel and she will facilitate discussion of these issues throughout the symposium.

Rethinking the Concrete-Abstract Distinction in Early Cognitive Development and Education

Many researchers have suggested that young children's thinking is inherently concrete. According to this view, young children learn about the world through direct exploration, rather than from abstract, symbolic representations. Although this characterization of children's thinking has been challenged (e.g, Simons & Keil, 1995), it continues to influence the design of educational curricula and materials. Young children are often encouraged to play with concrete letters, numbers, or mathematics manipulatives, based in part on the assumption that they will acquire the symbolic representation of letter or number best through the manipulation of concrete materials. Our research has been exploring the validity of this assumption in a variety of domains. We (*Uttal & DeLoache*) are testing under what conditions the use of concrete objects facilitates the development of literacy and mathematical thinking. We have found that a critical transition involves learning to think beyond the concrete properties of the objects. For example, we have asked 3-year-olds to play with concrete numbers or shapes. Children who had high levels of number knowledge played less with the objects as toys. Likewise, playing with concrete letters actually made it harder for children to think of the letters as representations. We interpret our results in terms of DeLoache's (2000) *dual representation* hypothesis. Playing with objects that are later intended to be symbols may actually be counterproductive; it focuses children's attention on the concrete properties of objects rather than on what they are intended to represent. Although concrete objects may indeed be appealing to young children, children must eventually learn to look past the concrete properties of the objects to the intended representations. Educators must balance the advantages of using concrete objects with the possible disadvantages.

The Role of Concreteness in Learning and Transfer of Abstract Concepts

How do people acquire abstract concepts that afford an unlimited number of instantiations sharing little or no surface similarity? The same mathematical concept can describe situations as superficially diverse as the metabolism of medication in the body and the temperature of cooling cup of coffee. How is knowledge of one instantiation transferred to a novel analogous situation? We (*Kaminski, Sloutsky, & Heckler*) argue that surface features may play an important part in this process: while concrete, contextualized, and perceptually-rich surface features may interfere with acquisition of the abstract concept, more impoverished surface features may be conducive for both learning and transfer. We have conducted a series of experiments investigating learning and transfer of conceptual knowledge as a function of the type of instantiation initially learned. Participants learned instantiations of a simple mathematical concept that were either concrete (i.e., contextualized or perceptually-rich) or impoverished and generic. We found that while some concreteness can facilitate initial learning, it significantly hindered transfer. Participants were unable to recognize and align common structure when expressed in a novel context. In addition, learning multiple concrete instantiations offered no benefit over learning only one. However, when participants were given the correspondence of analogous elements across learning and transfer instantiations, they did successfully transfer. These results suggest that concreteness can encapsulate structural knowledge creating an obstacle to transfer. At the same time, participants who learned a generic instantiation were able to spontaneously align structure and transfer. These findings add to the knowledge of mechanisms underlying analogical transfer and also have important implications for educational theories.

Compared to What? How Different Types of Comparison Facilitate Transfer in Mathematics

Comparison is emerging as a fundamental learning mechanism and an important teaching approach. We (*Rittle-Johnson & Star*) have worked to identify and combine key findings on comparison from cognitive science and mathematics education to improve transfer in mathematics learning. In Experiment 1, seventh-grade students learned about algebra equation solving over three classroom periods by either 1) comparing and contrasting alternative solution methods or 2) reflecting on the same solution methods one at a time. Students who compared solution methods became more accurate problem solvers, particularly on transfer problems. This provides experimental evidence to support one component of reform efforts in mathematics: encouraging students to share and compare alternative solution methods (e.g., NCTM, 2000). However, research from cognitive science has focused on a different type of comparison: examples with different surface features, but the same solution method (i.e. comparing isomorphic problem; Gick & Holyoak, 1983; Gentner, Loewenstein & Thompson, 2003). The purpose of Experiment 2 was to explore which types of comparison are more effective at supporting transfer in mathematics. Seventh-grade students either 1) compared isomorphic problems with the same solution method, 2) compared different problem types with the same solution method, or 3) compared different solution methods to the same problem. Preliminary findings suggest that condition interacted with prior knowledge. Comparing isomorphic problems seemed to facilitate transfer for students with lower prior knowledge, but comparing solution methods seemed to facilitate transfer for students with higher prior knowledge. Although there is general agreement that comparison is important for knowledge transfer, attention to what is being compared and by whom (e.g. low- or high-knowledge learners) is critical to understanding comparison and to supporting great transfer in mathematics learning.

Grounding, Contextualization, and Transfer

The goal of education is frequently to get students to apply their knowledge to new situations. For example, biology teachers want their students to understand the genetic mechanisms underlying heredity, not simply how pea plants look. A successful educational practice in this case would enable students to take genetics knowledge learned in the context of peas and apply it to dog breeds or human traits. This focus on acquiring transferable principles is well justified because the same principle often is relevant to different domains.

Taking as a case study psychology students' learning of Signal Detection Theory (SDT) principles, we (*Goldstone & Son*) have explored the potential of several tutorial strategies for promoting transferable knowledge. Students originally learn about SDT in a scenario involving a doctor diagnosing a disease based upon blood cell appearance, and then are transferred to a scenario where farmers must categorize melons appropriate for export based upon imperfect evidence. We find that grounded, perceptual diagrams offer benefits for transfer, but that other kinds of contextualization are disadvantageous. Contextualizing the principles by giving students actual experience with a blood cell categorization task or by encouraging students to identify with the doctor decreased the transfer of knowledge from the initial to the final scenario. I discuss these results in terms of situated, contextualized, and embodied learning, and propose preliminary prescriptions for the kinds of grounding that we should, and should not, aim for during education.

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