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# On the Relationship Between Knowing and Doing in Procedural Learning

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What is the relationship between learners' knowledge of concepts and their ability to execute procedural skills? In this paper, I draw from research in mathematics education, cognitive psychology, and developmental psychology in order to examine how knowledge of procedures and concepts has been studied and what conclusions have been reached about the relationship between them.

Three observations can be made from a review of the existing literature on the relationship between concepts and procedures in children's mathematics learning. First, most research in this area has tried to determine the optimum developmental relationship between concept and procedure learning. In other words, most studies have sought to answer the question, "Which comes first?" Second, almost all research in this area has been limited to the learning of topics in elementary school mathematics. Notably absent are studies of the development of procedural and conceptual knowledge in algebra, geometry, and calculus. Third, knowledge of concepts and knowledge of procedures are assessed in very different ways. Knowledge of concepts is often assessed verbally and through a variety of tasks. It appears that conceptual knowledge is viewed to be complex and multi-faceted. By contrast, procedural knowledge is assessed non-verbally by observing the execution of a procedure. Procedural knowledge is viewed as an entity that a student either has or does not have.

It is this final point that I wish to explore in more depth. The current assumption in the field is that the endpoint of acquisition for concepts is when they are "understood". By contrast, the endpoint of acquisition of procedures is when skills become routine and can be executed with fluency; in other words, when such knowledge has become automatized. I suggest that this portrayal of procedural knowledge does not adequately reflect the complex ways in which procedures can be known or even understood.

What might it mean to have understanding of a procedure? I mention three descriptions of what "procedural understanding" might look like. First, Davis (1983) writes about the process that a student goes through in planning how to approach an unfamiliar problem. Such planning requires that the student have knowledge of a range of necessary techniques, each with an appropriate cognitive label or "tag" which specifies what the technique can accomplish and its relevant goals and subgoals.

Second, Ohlsson and Rees (1991) propose that a procedure is executed with understanding when the "problem solver monitors his or her performance on the problem by comparing the successive states of the problem with

what he or she knows about the task environment" (p. 108). They propose that there are two types of knowledge of the task environment: One is knowledge of the principles which guide events and objects in the domain and the other is knowledge of the purposes of each step in a procedure. This second type of knowledge about the procedural task environment -- knowing the purposes of each step in a procedure -- is very similar to Davis' (1983) planning knowledge.

Third, VanLehn and Brown have written about teleological semantics (VanLehn & Brown, 1980). The teleological semantics of a procedure is "knowledge about [the] purposes of each of its parts and how they fit together. ... Teleological semantics is the meaning possessed by one who knows not only the surface structure of a procedure but also the details of its design" (p. 95). VanLehn and Brown (1980) note that a procedure can be cognitively represented on multiple levels. On a very superficial level, a procedure may be represented simply as a chronological list of actions or steps; on a more abstract level, a procedure can include planning knowledge in its representation. Planning knowledge includes not only the surface structure (the sequential series of steps) but also "the reasoning that was used to transform the goals and constraints that define the intent of the procedure into its actual surface structure" (p. 107).

According to these three views, to understand a procedure is to have planning knowledge -- knowledge of such things as the order of steps, the goals and subgoals of steps, the environment or type of situation in which the procedure is used, constraints imposed upon the procedure by the environment or situation, and any heuristics or common sense knowledge which are inherent in the environment or situation. I suggest that this expanded view of procedural knowledge can lead to better theory about the development of procedural and conceptual knowledge.

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