

contradictory, erroneous, or unnecessary concepts, with the result that learning and problem solving become difficult and ineffective.

Tracking the development of learners' mental models through the transition from novice to expert can be a means for determining what next steps in instruction should be taken (Gagné & Glaser, 1987). In a developmental study, Carey (1985a) documented changes in children's concept of alive as they gained domain-specific knowledge about biological functions. Likewise, Siegler and co-workers (Siegler & Klahr, 1982; Siegler & Richards, 1982) found that children's reasoning about balance-scale problems was greatly influenced by experience with new information. Using a task analysis procedure to determine what theory guided children's performance, Siegler was able to match their current knowledge state with learning events that helped them move to a new level of reasoning.

Teachers' knowledge of students' problem-solving knowledge has also been associated with problem-solving achievement. Peterson, Carpenter, and Fennema (1989) concluded that more knowledgeable teachers appeared to pose problems to students, question their problem-solving processes, and listen to their solutions. These actions were related to problem-solving achievement. Less knowledgeable teachers, by contrast, tended to explain problem-solving processes to students, "thereby also doing the thinking for students" (Peterson et al., 1989, p. 568).

How can teachers ascertain the mental models of their students? There are at least four possible ways to do it: (1) Observe them; (2) ask them for an explanation; (3) ask them to make predictions; and (4) ask them to teach another student (Jih & Reeves, 1992). A mathematician who does research on math instruction, Schoenfeld (1985) often asks his students without warning to explain their reasoning on a problem or to justify the approach they are taking to solve it. Not only does this enable him to judge their mental models, but also the tactic encourages students to monitor their own mental models. "By the end of the term, I don't need to ask questions anymore. Students have gotten into the habit of analyzing where they are" (Schoenfeld, quoted in *A Mathematician's Research on Math Instruction*, 1987).

By understanding what models learners are currently using to guide their performance, teachers and designers can build upon them by specifying what Glaser (1984) called pedagogical models. These may be the same as conceptual models that have been invented to make some system understandable, or they may be a series of approximations that may be thought about and debugged in the course of instruction. diSessa (1982) referred to a kind of task analysis for identifying components of preexisting theories that can be involved in developing more sophisticated theories. Collins and Stevens (1982, 1983) offered a model of inquiry instruction that provides strategies for helping learners make predictions from and debug their current models of understanding (see Chapter 7 for more discussion of this

model). For example, Anderson (1982) showed how learners in formulating models of heat transfer (e.g., temperature by getting them to think about the temperatures of specific objects) can be helped (e.g., Gagné & Glaser, 1987, and Lewis et al., 1987) to allow physics students to experiment with these results to the point of comparing these results to the model.

Finally, mental models can be used as a performance (Gagné & Glaser, 1987) and as a constant supplement to teaching. When students develop their own conceptualizations of a problem, their models can be built upon (p. 108). Choosing an appropriate model, however, can be a difficult task. For example, students learned to use a text editor, but the model between providing an incorrect model and conveying a complete model is a fine line. Providing different conceptualizations, each designed to elucidate a different aspect of the target.

For pedagogical or conceptual models, they should meet three basic criteria (Norman, 1983). A good model should be information that is highly familiar to the learner that it corresponds to important concepts. For example, the concept of a model as well as how these concepts are used to operate (Mayer & Gallini, 1983). It should be a complete model of the target. If this is the case, the model should conceptualize the desired information. Finally, a good model is easy to use in the information-processing system. The model should be models over a complete model.

Acquisition of a mental model is a process, however. "To plan a mental representation, you must go through it" (Perkins & Unger, 1982). Amaya's class in "A Lesson in Learning" explain various functions of the Supreme Court ruling on the right to privacy in their own lives?