Research Matters / Helping Students Develop Schemas

Bryan Goodwin

Let's show students the processes experts use to tackle problems.

In May 2009, a momentary glitch on Air France Flight 447 sealed the fate of all 288 souls aboard. As the Airbus left the coast of Brazil and headed over the Atlantic, Pierre-Cédric Bonin, a young pilot with limited hours in the cockpit, sat at the controls. Shortly before 11 p.m., the plane encountered ice above some thunderheads; that ice clogged its gauges, generating faulty readings inside the cockpit and turning off the autopilot.

Had Bonin and his (equally inexperienced) copilot done nothing at all, they likely could've landed the plane safely. Instead, as related in an article by William Langewiesche (2014), Bonin panicked. He pulled back on the stick, pitching the plane steeply upward and sending it into a spin-stall. Again, he could've solved the problem by doing nothing; the plane would've returned to a level path. Yet he kept trying to solve the problem the only way he could think of—by pulling back on the stick. By the time his senior captain awoke from a nap and rushed to the cockpit, it was too late. Moments later, they plunged into the dark ocean.

This tragic case of inexperience in the cockpit illustrates an important insight from research about what it takes to solve complex problems: expert *schemas*.

Learning from Chess

Much of what we know about how experts solve problems comes from studying chess grandmasters, who can quickly memorize the location of pieces on a chess board—unless those pieces are placed *randomly* on the board. As this latter detail indicates, the masters don't have photographic memories, but rather an acquired ability to see *patterns* resulting from moves (De Groot, 1966). Similar abilities have been found among experts who solve complex problems in other arenas. Experts see problems more clearly and can select among multiple possible strategies to solve them.

According to seminal work on the topic (Newell & Simon, 1972), what experts have that novices lack are *schema* that allow them to (1) categorize a problem; (2) construct a mental representation of it; (3) search for appropriate problem-solving strategies; (4) retrieve and apply those strategies; (5) evaluate the problem-solving strategies; (6) repeat steps 1 to 4 if they don't arrive at a solution; and (7) store that solution for later use. At the heart of these schema are two kinds of knowledge—declarative (knowing *what*) and procedural knowledge (knowing *how*)—that experts integrate. When they face a complex problem, the experts rely on their declarative knowledge to understand it and their procedural knowledge to solve it (Nokes, Schunn, & Chi, 2010).

A small-scale comparison of novices (first-year college students) and experts (doctoral students) further illustrates how experts use schema when tackling complex problems—in this case, researching and writing a 400-word essay on whether it's best to follow printed expiration dates or trust our senses when consuming perishable foods (Brand-Gruwel, Wopereis, & Vermetten, 2005). The biggest differences researchers observed were that experts spent more time than novices on sizing up and categorizing the task, reflecting on prior knowledge, evaluating information, and reformulating their theses based on new information. Perhaps most important, they showed a stronger grasp of the problem-solving process, which allowed them to better assess their progress by asking questions like, "Is this the information I need?" and "Am I still working toward an answer to my question?"

Don't Throw Students into the Deep End

What all this suggests for educators is that we cannot ask students to solve complex problems without first helping them develop the declarative and procedural knowledge needed to tackle such problems. Simply throwing students into the deep end of complex problem solving doesn't help them develop the schema or procedural skills they need to solve the problem.

That's the conclusion John Sweller (1988) drew after conducting a series of seminal studies in the 1980s: Simply challenging students with complex problems—like, "A car that starts from rest and accelerates uniformly at 2 meters/s/s (meters per second squared) in a straight line has an average velocity of 17 meters per second. How far has it travelled?"—does little to help them develop complex problem-solving skills. Why? Because novice students expend a great deal of mental bandwidth juggling back and forth between figuring out *how* to solve a problem and *solving* it. As a result, they may arrive (laboriously) at a correct answer, but haven't developed any schema for future use. As Sweller observed, "goal attainment [getting the right answer] and schema acquisition may be two largely unrelated and even incompatible processes" (p. 283).

To understand the power of expert schemas, consider veteran pilot John "Sully" Sullenberger's emergency landing of a 727 plane in the Hudson River just months before the Air France disaster. An expert pilot with 10,000-plus hours of flying time under his belt, Sully quickly sized up his problem (engine failure due to geese striking the turbines), drew upon in-depth knowledge of his aircraft (how far it could glide without power and its structural integrity after water impact), and used well-honed skills to land his aircraft and save 155 lives. Sully did all this instinctually and quickly.

This last fact points to the enigmatic nature of schema. Once we've developed them, our declarative and procedural knowledge become so intertwined that it can be difficult to separate them or retrace the steps we took to develop the expert schema we now employ automatically. Therein lies a core challenge with teaching complex problem solving to students: To help students solve such problems, we must *deconstruct* the expert schema—the declarative and procedural knowledge that underlie those schema.

One place to start is by making the processes experts use to solve problems—accessing prior learning to understand the problem, selecting from among a repertoire of strategies, and reflecting on their learning so they can tackle similar problems later—explicit. Perhaps most important, we can help students understand the power of schemas, whether for predicting the speed of bodies in motion, researching an interesting question, or piloting an aircraft in distress.

References

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Bryan Goodwin is president and CEO of McREL International, Denver, Colorado. He is the lead author of *Balanced Leadership for Powerful Learning*(ASCD, 2015).