Chapter 67
The TPACK of Dynamic Representations

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ABSTRACT

Effective teachers across K-12 content areas often use visual representations to promote conceptual understanding, but these static representations remain insufficient for conveying adequate information to novice learners about motion and dynamic processes. The advent of dynamic representations has created new possibilities for more fully supporting visualization. This chapter discusses the findings from a broad range of studies over the past decade examining the use of dynamic representations in the classroom, focusing especially on the content areas of science, mathematics, and social studies, with the purpose of facilitating the development of teacher technological pedagogical content knowledge. The chapter describes the research regarding the affordances for learning with dynamic representations, as well as the constraints—characteristics of both the technology and learners that can become barriers to learning—followed by a summary of literature-based recommendations for effective teaching with dynamic representations and implications for teaching and teacher education across subject areas.

DYNAMIC REPRESENTATIONS AND TEACHER KNOWLEDGE

The K-12 school curriculum presents a significant amount of content to students that they are expected to understand without being able to see firsthand, especially in the middle school and secondary levels. This content may require abstract thinking (e.g., place value, solving equations, and linear programming in mathematics), or it may require them to internalize concepts and processes that are invisible or too fast or too slow or too far away to be observed from the classroom (e.g., molecular structure, Newtonian physics, distant geographic landforms, etc.). Visualization, spatial thinking, and the ability to understand and translate representations in multiple forms are highly valued skills for success in school, especially if students

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are not just to memorize but *understand* what they are supposed to be learning (Jiang & McClintock, 2000; Linn, 2003; National Council of Teacher of Mathematics, 2000; Newcombe, 2010). Yet, students have long struggled with curriculum requiring these skills, and many fail to develop conceptual understanding of the content (e.g., see Leinhardt, Zaslavsky, & Stein, 1990; White & Mitchelmore, 1996).

Visual representations, such as illustrations, photographs, graphs, maps, analogies, physical manipulatives, and three-dimensional models, are often used by effective teachers to promote conceptual understanding, but these static representations remain insufficient for conveying adequate information to novice learners about motion and dynamic processes (Rohr & Reiman, 1998). The advent of personal digital technologies has created new possibilities for more fully supporting visualization, however. Pictures and graphs may be animated, displaying changes in space over time; interactive simulations can set into motion models based on real data; three-dimensional maps and models can be rotated and zoomed in or out; two- and three-dimensional geometric figures can be resized, rotated, and reshaped; and digital video, which is easier than ever to access and create, can capture actual events for repeated viewing and analysis. Multimedia environments can even combine multiple dynamic representations, linking them so that users can see the effects of changes made to one representation in all the others.

Some educators see all this capability for motion as intuitively beneficial, asserting that a dynamic representation of a dynamic phenomenon is more authentic and should be an obvious means for increasing student comprehension and conceptual understanding (e.g., McKagan et al., 2008; Ploetzner & Lowe, 2004). The literature includes numerous small-scale studies that support this conclusion (many of which will be cited in this chapter). In their meta-analysis of 26 studies, for example, Hoffler and Leutner (2007) found that representational animations produced significantly superior learning outcomes in students than did representational static pictures. The authors defined representational animations as explicitly presenting the topics to be learned and not there merely as motivational devices.

On the other hand, a number of researchers have presented students with animations and other dynamic representations and found their learning outcomes to be *inferior* to the learning of students viewing one or more static images of the same phenomenon (Lewalter, 2003; Lowe, 2003; Tversky, Morrison, & Betrancourt, 2002). As Ploetzner and Lowe (2004) concluded,

It is clear that under suitable circumstances [dynamic] representations do have considerable potential for facilitating the learning of dynamic subject matter. However, in many cases, merely making dynamic visualizations available to learners is probably insufficient for this potential to be fulfilled. (p. 293)

As researchers have sought to understand what conditions must be in place for students to learn from these powerful visualization technologies, teacher knowledge rises to the forefront as key. Teachers who have a deep knowledge of their content and of the concepts students have most difficulty grasping can apply their understanding of digital technologies to select the best form of dynamic representation when appropriate. When they select a dynamic representation from among the many tools in their pedagogical toolkit, these teachers are aware of the advantages and disadvantages of different computer interfaces (Mayer, 2009; Kozma, 2003). They know how to mitigate the potential overload on students' cognitive capacities that may impede their learning (Lewalter, 2003; Mayer, 2009). They also know how to incorporate the representation into their instruction in ways that best support student learning (Lowe, 2003, 2004; Niess, 2005, 2008). This cumulative knowledge is, of course, referred to as technologi-