Chapter 10
PhET Interactive Simulations: New Tools to Achieve Common Core Mathematics Standards

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ABSTRACT

This chapter focuses on the design and use of interactive simulations as a powerful tool for learning mathematics. Since 2002, the PhET Interactive Simulations project at the University of Colorado Boulder (http://phet.colorado.edu) has been developing and studying the use of interactive simulations in teaching and learning STEM. While the project’s initial work focused on science learning, the project now includes a significant effort in mathematics learning. In this chapter, the authors describe the PhET project, including theoretical perspective, design goals, and research-based simulation design principles. They demonstrate how these design principles are applied to simulations, describe how they support achievement of the Common Core State Standards for Mathematics (CCSSM), and provide supporting evidence from individual student interviews. Finally, the authors discuss various approaches to using these simulations in class and provide guidance on leveraging their capabilities to support knowledge construction in mathematics in a uniquely engaging and effective way.

INTRODUCTION

The use of tools—concrete manipulatives, calculators, measurement devices, computers, etc.—has long been recognized as important in mathematics education, and advances in Computer Technology (CT) position virtual manipulatives and interactive simulations as powerful new tools for teaching and learning mathematics. National Council of Teachers of Mathematics (NCTM), 2000) Technology Principal asserts that students can learn more mathematics more deeply with the appropriate
use of technology because it allows students to shift their focus from computation to reflection, decision making, reasoning, and problem solving. Educational research adds support to NCTM’s call for the use of technology for teaching and learning mathematics. In a meta-analysis of relevant literature, Li and Ma (2010) concluded that CT can positively impact mathematics achievement.

Lei (2010) argues that the quality of educational technology—what and how it is used—is more predictive of student outcomes than the quantity of technology students interact with. Research supports Lei’s notion that the first aspect of the quality of instruction—the what—is important. Characteristics of CT that impact student achievement include allowing students to experiment and test hypotheses, scaffolding students to avoid common error patterns (Suh, Moyer, & Heo, 2005), providing immediate feedback (Reimer & Moyer, 2005), and presenting information in multiple representational forms (Li & Ma, 2010; Roschelle et al., 2010; Vahey, Lara-Meloy, Moschkovich, & Velazquez, 2010). For example, in a large-scale study examining the impact of an interactive representational technology, Roschelle et al. (2010) found that students in the treatment classes performed equally well on standardized measures of basic mathematical knowledge and significantly better on measures of advanced mathematics than control group students who received “business as usual” instruction.

Regarding the second aspect of the quality of technology—how it is used (Lei, 2010)—Li and Ma (2010) found in their meta-analysis that effect sizes of CT were greatest when combined with instruction that aligned with mathematics reform. Other studies also suggest that instruction aligned with constructivist principles rather than drill and practice is necessary for CT to be effective (e.g., Vahey et al. 2010; Wenglinsky, 2005). For instance, problem solving is a key component of mathematics reform, and the use of CT in a problem-based learning environment was found to support students in developing computation and problem-solving skills (Bottge, Grant, Stephens, & Rueda, 2010). Reform instruction also stresses the use of manipulatives, and virtual manipulatives have been found to be as effective as, and sometimes more than, concrete manipulatives for improving student learning (Burns & Hamm, 2011; Lee & Chen, 2010; Moyer-Packenham & Westenskow, 2012; Moyer-Packenham & Suh, 2011; Reimer & Moyer, 2005; Suh et al., 2005; Yuan, Lee, & Wang, 2010). The immediate feedback provided by virtual manipulatives is important for helping students monitor their own understanding and learning of concepts, and they are easier and faster to use than concrete models or paper and pencil tools (Reimer & Moyer, 2005). Other aspects of reform mathematics teaching found to support students of various backgrounds and ability levels in learning from CT include: ample opportunities for discussion with peers (Vahey et al., 2010; Zahner, Velazquez, Moschkovich, Vahey, & Lara-Meloy, 2012); a focus on meaning and student construction of informal rules before formal introduction of rules and vocabulary (Suh et al., 2005; Vahey et al., 2010; Zahner et al., 2012); and addressing incorrect answers using higher-level moves (Zahner et al., 2012).

In this chapter, we introduce the PhET Interactive Simulations project at University of Colorado Boulder and explore in detail what aspects of the design make PhET simulations unique and effective, and how teachers can effectively integrate the simulations into their instruction. Since 2002, the PhET project has focused on understanding and leveraging the educational potential of interactive simulations through a combined effort of research and development. Here, we aim to provide a basis of knowledge about the design and use of PhET simulations that will support educators in (1) recognizing the multiple affordances provided by simulations, (2) better understanding how these affordances influence learning, and (3) effectively designing and implementing instruction that leverages these affordances to address the new Common Core State Standards for Mathematics (CCSSM).