Chapter 7
The Power of Computational Modeling and Simulation for Learning STEM Content in Middle and High Schools

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ABSTRACT

Using Squeak Etoys to Infuse Information Technology (USeIT) was designed to offer expanded information technology experiences to 155 middle and high school students over a three-year period by exploiting the Squeak Etoys media authoring tool as a simulation and modeling environment. Through problem-solving activities and development of Squeak Etoys modeling projects, USeIT investigated the impact of Problem-Based Learning (PBL) and utilization of Squeak Etoys on student understanding of scientific and mathematical concepts. A design-based research method was used to collect data. The results revealed that when simulation and modeling are used under specific learning conditions, a deeper level of understanding of key science and mathematics concepts is observed. In addition, problem-based simulation tasks cognitively engaged students, particularly those who otherwise did not see the relevancy of STEM content in their lives. Less motivated students developed interests in STEM content and showed confidence in their abilities to learn mathematics and science.

INTRODUCTION

As a result of growing concern that the United States is not preparing a sufficient number of students, teachers, and practitioners in the areas of **S**cience, **T**echnology, **E**ngineering, and **M**athematics (STEM), improving learning in STEM education continues to be a priority for American policymakers (Congressional Research Service, 2011). In recent years, the National Science Foundation (NSF) and other

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organizations have supported innovative projects that aimed to develop examples of rich, learner-centered educational reform in STEM fields. "Using Squeak to Infuse Information Technology (USeIT)" was one of these projects. In partnership with local schools, the USeIT project was designed to develop examples of rich, learner-centered simulation and modeling learning activities in STEM fields.

The purpose of this chapter is to report the impact of integrating Problem Based Learning (PBL) and computational modeling using *Squeak Etoys* technology on student learning of STEM contents. It specifically describes the changes in students' understanding of the key scientific and mathematical concepts and students' thinking skills when constructing models of complex systems.

BACKGROUND AND RELATED LITERATURE

STEM Education

STEM Education is defined in many ways by different groups. A common definition of STEM education refers to science, mathematics, and technology educators working together to explore and implement integrative alternatives to traditional, disconnected STEM education (Congressional Research Services, 2012; National Science and Technology Council, 2011). The integrative STEM education is expected to combine technological design purposefully with scientific inquiry, engaging students or teams of students in scientific inquiry situated in the context of technological problem solving. STEM educators have made an increasing effort to employ the integrative approaches using various strategies (Becker & Park, 2011). However, in spite of the emphasis and many efforts to disseminate and implement STEM education, there is limited research on the effects of the integrative approaches among STEM subjects on the students' understanding of scientific and mathematical concepts (Becker & Park, 2011; Hurley, 2001; Judson & Sawada, 2000; Pang & Good, 2000; Venville, Wallace, Rennie, & Malone, 2000). Moreover, recent meta-analysis of effects of integrative approaches in STEM on student learning (Becker & Park, 2011) shows that while integrative approaches provide a rich learning context and improve student learning and interest, the types of integration impact the effects of these approaches among STEM subjects.

Problem Based Learning Pedagogy for STEM Education

PBL is a non-traditional, active, inductive, student-centered approach that focuses on the introduction of a real-life problem (Ehrlich, 1998). In PBL environments students are presented with complex, authentic, meaningful problems as a basis for inquiry and investigation. Sometimes called a project, an inquiry, or an authentic investigation, the problem, as a complex task, is formed by the need to design, create, evaluate, revise, and/or improve something. Research on PBL--particularly in medical fields--suggests that PBL results in gaining complex levels of knowledge, such as comprehension and analysis of problems and improving student attitude and satisfaction. While not abundant, a growing body of research also suggests that PBL is an effective strategy for increasing students' understanding of STEM content, IT, and problem-solving skills (e.g., Barron & Darling-Hammond, 2010; Denner, 2007; Dischino, et. al. 2011; Huelskamp, 2009; McGrath, Lowes, Lin, & Sayres, 2009; Stone, 2011). PBL strategies also have been shown to enhance students' attitudes and interest toward learning STEM subjects and to help them explore future opportunities (e.g., Dischino, et. al. 2011; Cerezo, 2004; Kuo-Hung, Chi-Cheng, Shi-Jer, & Wen-Ping, 2013; Lou, Shih, Diez, & Tseng, 2011).

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