Chapter XII
Supporting Discovery-Based Learning within Simulations

Lloyd P. Rieber
The University of Georgia, USA

ABSTRACT

This chapter presents a review of research on the use and role of interactive simulations for learning. Contemporary theories of learning, instruction, and media, suggest that learning involves a complex relationship and dependency between a learner's prior knowledge, a learner's motivation, the context, the task, and the resources (e.g., simulations) provided to, and used by the learner to support or enable the task. Given this perspective, and data from an evolving research program, simulations are best used to help learners construct knowledge and make meaning by giving them control over phenomena modeled by the simulation. Several theoretical frameworks have guided this research program: dual coding theory, mental models, and constructivist learning theory. An overall result of this research is that learning should be based on experience, such as that derived from interacting with a simulation, and supported with explanations. This is counter to traditional educational wisdom where explanations rule instructional strategies.

INTRODUCTION

Since the late 1980s, I have studied children and adults using educational simulations based on various pedagogical (e.g. inductive and deductive learning) and philosophical approaches (i.e. constructivist and objectivist). My goal in this chapter is to summarize some of this research and also provide some of the background that frames my research questions. As an instructional technologist, I have been influenced by the use of instruction to shape learning, but as someone who accepts a constructivist orientation to learning, I know that instruction is but one path to learning. When given little or no instructional support, I am interested in the strategies that people use to

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learn given the opportunities of an interactive simulation. Even more important, I am interested in those times when they run into problems and need help. My goal is not to withhold instruction from them, but to gain a better understanding of when instructional support is unnecessary or, conversely, most needed.

The general conclusions I have drawn from this research and experience are not neat and tidy. I am unable to say that simulations are "better" than other learning approaches. One of the most important conclusions is simply that learning with simulations is heavily context-bound (Kluge, 2007). The influence or role of a simulation on learning is interrelated to the other elements of the instructional system. This is a useful reminder that human cognition and motivation are among the most complex phenomenon we can study. As a researcher, this generates curiosity in me leading to more research. Yet, as an educator, I admit that I grow restless at times when design principles prove elusive.

This chapter is presented in three sections. First, I discuss important background on visualization principles needed in the design of highly visual educational simulations. This background section in presented in two parts: 1) a brief overview of visualization in education; and 2) theories relevant to the simulation research considered afterwards. The two theories I emphasize are dual coding theory, a well-established and studied theory that offers much guidance in deciding when and how to design visualization for educational materials, and mental models, a theory that attempts to model and explain human understanding of complex phenomena. In the second section, I present the main thrust of the chapter by considering what is meant by interactive multimedia, basing most of my discussion on the use of simulations. However, I also consider how attributes of microworlds and gaming can influence simulation design. I then turn attention to some recommendations and implications for design. I use the relatively new literature on universal design for learning (UDL) as an additional lens for understanding the implications. Although UDL focuses on people with disabilities, one might argue that we all have challenges to learning depending on the context we find ourselves in, the materials and resources given to us, and expectations placed on us. The label "disability" is often attached to people facing such challenges in arbitrary and unfortunate ways. Finally, I offer some conclusions and consider future research directions.

BACKGROUND

Visualization in Education: A Primer

The decision to incorporate visuals as part of instruction or training is often made without a well-articulated justification or rationale. The lack of a firm set of design criteria can lead to unexpected results. Research has demonstrated conditions under which visuals – static and dynamic —are generally effective, as well as those where graphics serve no purpose or, worse, do harm (Levin, Anglin, & Carney, 1987; Mayer, 2001, 2005; Rieber, 1994). For example, consider the cultural symbolism of the owl. Many American teachers like to adorn their classrooms with fanciful images of a friendly wise owl to symbolize an educated person. Yet, an owl often represents an evil omen for many Native Americans, leading some students to be alienated by such graphics. All designers should carefully consider the impact of such innocent graphics in their materials.

The use of graphics in education can generally be classified three ways (Alesandrini, 1984; Rieber, 1994): Representational, analogical, and arbitrary. Representational graphics physically resemble the object they are designed to represent. For example, an instructional text describing a Venus fly trap plant probably would be accompanied by a picture of this plant. This seems simple enough, but what kind of picture should be used? Representational visuals range somewhere be-

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