Chapter 29
How People Learn with Computer Simulations

Douglas L. Holton
Utah State University, USA

ABSTRACT

Using the four lenses of the How People Learn (HPL) framework, this chapter reviews research on the use of computer simulations for pedagogical purposes. Deciding when and how to support effective learning with simulations requires careful consideration of learner-centered, assessment-centered, knowledge-centered, and community-centered issues. By reviewing educational research on simulations from these four perspectives, one may then be better equipped to incorporate simulations into instruction and training in a manner that can align and balance all four perspectives, resulting in a more effective learning environment.

INTRODUCTION

Imagine a beginning airplane pilot, a beginning surgeon, or a teenager getting behind the wheel of a car for the first time. In cases like these mistakes could have serious consequences, and it is for this reason a great deal of effort has been spent on the development and use of training, computer simulations and other practice experiences. There is no perfect substitute for direct experience and participation, but developing simulated experiences that mimic the real thing as closely as possible saves money and saves lives.

As science and technology advance too, the different domains in which we train and educate people are becoming more and more complex. Students have many difficulties learning about complex and dynamically changing systems and phenomena. There is a growing need for more powerful tools such as simulations and modeling tools to assist students and teachers with understanding these dynamic systems. This chapter reviews the use of computer simulations for this pedagogical purpose and argues that supplemental learner-centered de-

DOI: 10.4018/978-1-60566-782-9.ch029

sign strategies are needed to improve performance and learning outcomes.

First, however, one must develop a vocabulary to begin to make sense of dynamic systems, simulations, and learning and understanding. Hence, the first few sections introduce some of the terminology and concepts that will later be necessary for interpreting and applying a frameworkfor using and designing simulations for pedagogical and training purposes.

DYNAMIC SYSTEMS

Dynamic systems are typically made up of multiple interacting components, such as the parts of a car engine or the coordinated activity of the human respiratory system, and are characterized by behaviors that evolve in time. When normally using and interacting with such systems, we typically do not think about the underlying dynamic interactions involved. For example, we do not usually consider nor need to consider the mechanics of breathing or the combustion processes occurring inside a car engine. We may think only of the function and purpose of a system, such as a car engine's function in helping us transport to another location. When however the function of a system is uncertain or unfulfilled, such as when designing or troubleshooting or predicting the behavior of a system, we need to consider the underlying mechanics.

We typically construct models to better understand and predict the behavior of physical and social systems. The simplest type of model is an input-output model, or "blackbox" model. Behaviorism, for example, modeled human and animal behavior by observing relationships between input stimuli and observable output behavior. For a better understanding though we construct process models of systems that model not only external interactions but the structure, behavior and function of internal parts also. A structure-behavior-function (SBF) model consists of:

- **Structures** the stable components of a system, such as the parts of a car engine.
- **Behavior** the description an observer makes of the changes in the system over time and with respect to the environment with which a system interacts (Maturana & Varela, 1987), such as a person putting on a coat in response to colder temperatures.
- **Function** is the effect of a system on its environment (Chandrasekaren & Josephson, 1996, 2000), such as the function of a thermostat and heating system to keep a room at a constant temperature. As mentioned earlier, function is also a higher-level description of a system's purpose and how it is expected to operate within an environment.

This SBF framework has been used before to characterize people's descriptions of how systems and devices work (Goel, Gomez de Silva Garza, Grué, Murdock, Recker, & Govinderaj, 1996; Hmelo, Holton, & Kolodner, 2000; Hmelo-Silver & Green, 2002).

Any system may also be characterized by certain generic structures and interactions, and this has formed the basis for the field of system dynamics. There are two basic types of components that characterize how a system changes over time, sources of effort (also known as stockpiles) and flow components (Karnoop, Margolis, & Rosenberg, 1990). In a hydraulic braking system, for example, pressing a brake pedal causes a piston to move. The piston may act as an *effort* source by delivering energy into the hydraulic system in the form of pressure. This may result in a change in the rate of *flow* of fluid through the system. Energy is transmitted through the system and converted back into pressure onto brake pads, which dissipate the energy by exerting friction with the tires. Thus, energy may be stored, transmitted, or converted within a system by the effort and flow sources, but also dissipated to the surrounding environment. The speed of these energy changes, or *power*, is constrained by both the amount of effort and the

Related Content