Chapter 1.15
Simulation in Teaching and Training

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INTRODUCTION

Simulation has always been about learning. For being able to simulate something, a model of a system must be developed. Thus, the perspective of teaching and training with modeling and simulation is necessarily twofold. Sometimes the model builders are the primary learners. They learn by constructing models of scratch, and by changing model parameters. Sometimes the users of the simulation models are the target learners. They learn by interacting with a simulation. Sometimes, the learners are not aware that they interact with a simulation.

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Applications are manifold and can stem from such diverse teaching and training domains as, for example, physics (Rickel & Johnson, 1999, 2002), computer science (Martens & Uhrmacher, 2001), psychology (Künzel & Hämmer, 2006), medicine (Kinshuk, Oppermann, Rashev, & Simm, 1998; Kühnapfel, Çakmak, & Maaß, 1999; Shaw, Ganeshan, & Johnson, 1999), aviation (Dörr, Schiefele, & Kubbat, 2000), and also military training (McGlynn & Starr, 2001; Moon, Schneider, & Carley, 2006).

Teaching and training in modeling and simulations overlaps with research in intelligent tutoring systems (ITS) (Atolagbe & Hlupic, 1997). In combining modeling and simulation with ITS,

the ITS knowledge bases can be used for either steering the simulation run (Stottler, Jensen, Pike, & Bingham, 2002), providing the information for the models to be simulated (Martens & Himmelspach, 2005), or for giving advice and feedback (Bravo, van Joolingen, & de Jong,2006; Stottler et al., 2002). A simulation can also be a part of a teaching and training system, instead of being the complete teaching and training system itself. This can take place by integrating additional simulated actors in a role-play, as pedagogical agents (Rickel & Johnson, 2002), or by simulating the environment (Dörr et al., 2000; Kühnapfel et al., 1999). This is also true for game-based approaches (Siemer & Angelides, 1994).

Sometimes the teaching and training system is designed in a way that mimics a real-life situation without actually simulating something in the sense of "execution of a model." Examples of such systems, which are also called simulations, can be found in areas like medicine. A classical example is the "simulation" of a patient case (Zary, Johnson, Boberg, & Fors, 2006).

Last but not least, models and simulations can be used as part of the design phase of a teaching and training system. Examples would be introducing and simulating learner models for testing tutoring software, and development of models in the context of teaching and training systems (e.g., software models, didactical models, learner models, etc.). As models in teaching and training systems are manifold, this aspect will not be pursued further in this article.

BACKGROUND

In recent years, the term *simulation* has become part of everyday language. Unfortunately, this goes hand in hand with blurring its scientific meaning. In everyday language, simulation is often used in the sense of "the act or process of pretending," or as "imitation or enactment." In the medical or psychiatric sense, simulation is related to feigning. Here it means the (conscious) "attempt to feign some mental or physical disorder to escape punishment or to gain a desired objective" (simulation, 2007). The term simulation has its roots in the Latin term for imitation: *simulationem*. The term *emulation* (in the sense of imitating something), which is closely related to simulation, and which also plays a role in teaching and training, will not be discussed in this article (for further reference, see e.g., emulation, 2007).

Simulation of something always requires some sort of *model*. Even in the medical sense, the person feigning a disease needs at least a basic concept, that is, a model, of the disease. The term *model* can be traced back to the 17th century, when the ancient Italian term *modello* became famous in fine arts. In the common sense, a model is an image of reality. Nowadays, the usage of the term is extended. Models can be developed based on natural artifacts or things, on hypotheses, on theories, or even based on pure fiction. The modern interpretation of model is the object which is the result of a construction process. However, everyday language use of the term model is manifold; no single definition exists (see e.g., model, 2007).

From the perspective of computer science, a third term occurs in the context of modeling and simulation: the term *system*. A simulation in the context of science is sketched as: "the representation of the behavior or characteristics of one system through the use of another system" (simulation, 2007). Similar definitions can be found in the works of Zeigler, Praehofer, and Kim (2000) and Cellier (1991). The first system mentioned in the quotation is related to a fictitious or real system. This system shall be investigated. Usually there exists a hypothesis or a scientific question, which is the basis of an experiment. Often, experiments on real systems are not possible or not sensible. Reasons are that the experiment would take too long, would include too much risk, would simply not be possible, or the system is not available in