Chapter 1.4
Computer Simulations and Scientific Knowledge Construction

Athanassios Jimoyiannis
University of Peloponnese, Greece

INTRODUCTION

Information and communication technologies (ICTs) are increasingly expanded nowadays and undoubtedly constitute a vital component of our modern society influencing many aspects of our lives, such as administration, economy, culture, work environment, home life, and, most of all, education. In particular, multimedia and Internet technologies provide exciting opportunities for the integration of new tools in the curriculum in order to support teaching, to promote students' active engagement and enhance their ability to facilitate high order skills.

A number of ICT applications, such as computer-based laboratories, hypermedia and virtual reality applications, educational games, simulations and modeling tools, exploratory programming environments, intelligent tutors, and others are available for teachers and students (Jonassen, Howland, Moore, & Marra, 2003). Among the various ICT applications, computer simulations are of a great interest since they constitute open educational environments providing active engagement and practical experiences for learning and the understanding of concepts beyond their theoretical context.

Currently, the use of simulations covers a wide range of applications within the areas of research and analysis studies (Feinstein & Park, 2002; Hanan, Prusinkiewicz, Zalucki, & Skirvin, 2002; Mesa, Navarro, Steinmetz, & Eke, 2003; Washington, Weatherly, Meehl, Semtner, Bettge, Craig et al., 2000), system design (Axelrod, 1997;

DOI: 10.4018/978-1-60960-195-9.ch104

Lorek & Sonneschein, 1999), training and education (de Jong & Joolingen, 1998; Jimoyiannis & Komis, 2001; Lee, Nocoll, & Brooks, 2004; Ziv, Small, & Wolpe, 2000), entertainment (Leemkuil, de Jong, & Ootes, 2000), and physical therapy (Merians, Jack, Boian, Tremaine, Burdea, Adamovich, et al., 2002).

Computer simulations are becoming more generally recognised as efficient learning environments where students can explore, experiment, question, and hypothesise about real life situations (natural or social), which would be inaccessible otherwise. Simulations can offer substantial benefits in education by overcoming obstacles of doing experiments, through replacing real world systems, overcoming drawbacks of those systems, visualising invisible processes, and offering multiple views and multiple representations of the situated system.

In this article, the basic characteristics of scientific and educational simulations are discussed. Research findings which support their educational effectiveness are presented, and emphasis is placed on the pedagogical issues of designing and using simulation environments aiming at facilitating students' engagement and active knowledge construction.

SCIENTIFIC SIMULATIONS

Generally speaking, a simulation is a technique of imitating the behaviour of a situation, process, or system by means of an analogous system. In the simplest sense, a system is a set of interacting identities. In the case of scientific simulations, this analogous system is a *mathematical model*. The mathematical equations that produce the model represent the various processes which take place within the target system. In other words, this model constitutes a simplified or idealised representation of a system by means of a set of mathematical equations (algebraic, differential, or integral). The mathematical model becomes a simulation by solving numerically (i.e., for varying sets of input values) the equations comprising in order to imitate or simulate the dynamic (time-varying) behaviour of the system (Fishwick, 1995).

In a computer simulation, the mathematical model is produced by proper executable algorithms, which are used to solve the mathematical equations. Consequently, a computer-based simulation is a software application that embodies a model of the actual or theoretical system, executing the model on a computer and analysing the output. Any system in either the micro- or the macro-world can be simulated, providing that its behaviour can be described by a computer model (algorithm). Usually, a simulation model is an abstraction that behaves somewhat like the original system, thus allowing users to replicate only a small part of the actual system under investigation (e.g., its key features or characteristics).

The common perception of a simulation is that of an interactive computer program that replicates, within limits, some object, phenomenon, situation, or process of the real or the imaginary world. There is a confusion between simulations and other computer applications which have a similar-looking output like *animations* or *visualisations*. Simulations differ substantially because they predict an output based on a series of inputs. On the other hand, computer animations do not use any underlying model to calculate the behaviour of the system while they simply display a series of precalculated values. In conclusion, there are two key features which define a computer simulation (Thomas & Milligan, 2004):

- A *computer model* of a real or theoretical system that contains information on how the system behaves (formal entities, properties, and rules or relationships among them).
- *Experimentation* can take place; for example, the user can change the input to the model, thus affecting its output behaviour (Figure 1).

Related Content

Metamorphic Testing of Image Classification and Consistency Analysis Using Clustering
Hemanth Gudaparthi, Prudhviraj Naiduand Nan Niu (2022). *International Journal of Multimedia Data Engineering and Management (pp. 1-20).*
www.irma-international.org/article/metamorphic-testing-of-image-classification-and-consistency-analysis-using-clustering/304390

Prediction and Diagnosis of Heart Diseases Using Data Mining and Artificial Intelligence-Based Algorithms
Subhani Shaikand Vijayalakshmi Kakulapati (2023). *Using Multimedia Systems, Tools, and Technologies for Smart Healthcare Services (pp. 160-175).*
www.irma-international.org/chapter/prediction-and-diagnosis-of-heart-diseases-using-data-mining-and-artificial-intelligence-based-algorithms/314931

Mobile Financial Services in Developing Countries: The Impact on Consumer Financial Behaviour
Gordian Stanslaus Bwemelo (2018). *Mobile Technologies and Socio-Economic Development in Emerging Nations (pp. 47-63).*
www.irma-international.org/chapter/mobile-financial-services-in-developing-countries/201275

Another AI? Artificial Imagination for Artistic Mind Map Generation
Ruixue Liu, Baoyang Chen, Xiaoyu Guo, Meng Chen, Zhijie Qiuand Xiaodong He (2019). *International Journal of Multimedia Data Engineering and Management (pp. 47-63).*
www.irma-international.org/article/another-ai-artificial-imagination-for-artistic-mind-map-generation/245753

Productive Gaming and the Case for Historiographic Game-Play
Shree Durgaand Kurt Squire (2011). *Gaming and Simulations: Concepts, Methodologies, Tools and Applications (pp. 1124-1141).*
www.irma-international.org/chapter/productive-gaming-case-historiographic-game/49440