Foreword

Since some decades, computer simulations have become part and parcel of advanced learning environments. This book addresses the nature of simulation from multiple perspectives and within a variety of contexts in order to provide a foundation for its effective integration into education and learning.

Actually, while much has been written about models and simulations, little has been written about the underlying theoretical and epistemological foundations. In addition, there are also several shortcomings with regard to the instructional design principles and the varieties of ways for effective use of models and simulations in learning and instruction. This book provides a theoretically sound and practical guide for designing and using models and simulations to support learning in formal instructional contexts. Furthermore, it provides a comprehensive framework for conducting research on educational uses of models and simulations. This will be illustrated by examples of different types of simulations, including agent-based and system dynamics simulations in various contexts. The author provides the reader with a rationale and methodology for the design of interactive models and simulations along with a variety of applications ranging from the natural to the social sciences. Franco Landriscina makes clear that operating with simulations presuppose the application of mental models that provide the user with both a model of the system to be simulated and a model for reasoning in order to simulate the transformations of the system. Then, a simulation can be used to show the possible real effects of alternative conditions and courses of action. Consequently, the theory of mental models becomes a cornerstone of the theoretical argumentation which covers the broad range of theories and research on mental models – starting with the neo-pragmatic approach (e.g. Stachowiak) across cognitive-constructivist approaches (e.g. Johnson-Laird) up to the conception of model-centered learning and problem solving (e. g. my own work) that operate with computer-based simulations.

Thus, this book provides a state-of-the-art review of modeling for learning and problem solving in complex domains. Topics covered include the foundations of knowledge structures and mental model development, modeling for understanding, dynamic systems modeling, simulation-based learning, and simulations for thinking. The thread tying these chapters together is an emphasis on what the learner is doing and specifically on having learners engaged in modeling and simulation construction rather than merely interacting with pre-constructed simulations. Actually, very often learners use simulations as mere applications which have been designed by programmers and instructors. The learners often don’t get insights in the design of the tools itself, and therefore, they don’t understand the functions of modeling the world. Such simulations can be called black box models. In contrast, Franco Landriscina is pleading to engage learners in processes of understanding the models underlying the simulations. Such models can be called glass box models. They presuppose that the learners can check the conceptual and mathematical models that are use to run a simulation. Clearly, this part of the book is another cornerstone of the argumentation.

This book deals with these focal points from the perspective called model-centered learning and it provides an extension to the glass-box approaches: The author explores the learning impact of students when constructing models of complex systems in various subject matter domains. The act of modeling in this vein needs to include reflection upon the thinking processes and the function of the tools which the learner may apply for modeling. Human learning either yields to manage new situations or improve efficacy of known behavior. This dual approach of human learning is described as the interplay between schemas and mental models. Based on these cognitive tools the human mind is able to create new and artificial models of the world aiming at the simulation of what would happen if the world is manipulated in an certain way. This means that a "mental simulation runs" to imagine the events that would take place in the world if a particular action were to be performed. Thus, mental models allow one to perform entire actions internally and to judge the consequences of actions, interpret them, and draw appropriate conclusions. From the perspective of mental model research, Franco Landriscina moves in his book from the notion of models as a particular mode of internal representation mediating between images and propositions to the understanding of mental models as a tools of embodied simulation (by means of cognitive linguistics). This is a great extension of mental model theory that could serve as a fundamental basis for future research in this special field of interest.

Humans are probably the only creatures who can simulate complex scenarios in mind in order to anticipate changes of the real world. The theory of mental model takes most of those assumptions into account, when asking how individuals operate successfully with the world and its demands for intelligent behavior. Modeling and simulations are means that make humans smart.

It is of great importance to see all the chapters in this book as contributions to the question how people think, how they learn and how instruction can support those phenomena. Consistently, the book's focus is on the particular relevance of simulations and their unique roles to play in learning. This has to do with creating learning environments, whether simulated or virtual, which students can explore freely or within varying constraints required by guidance in order to construct knowledge on their own. The key to the success of this application of simulations is not so much in how the "message" itself is presented, but in the degree to which students can work out for themselves ways to reduce the dissonance between what the environment presents to the user and the knowledge and experience the user brings in when he or she enters the environment. An extended use of computer-based simulations as a tool to expedite the processes of problem solving may help shift the focus from the end product and from the pure acquisition of facts to cognitive processes like manipulation and understanding which them encourages curiosity and creativity. In this sense various features of simulation technologies may help students become better problem solvers.

Recent developments in interactive software, and the emergence of systems thinking provide a unique opportunity to create interactive model-based simulations that address student learning. Computer simulation programs encourage students to explore complex and realistic systems. The interactive environment and graphic capability of these programs provides instant feedback to the students. In addition to dynamic simulation capabilities, many of these programs allow the user to incorporate animation into the simulation.

Clearly, simulations are computer programs aiming at modeling complex systems' behaviors. They allow a learner to explore a system in a controlled way in order to better understand how the system components interact, and how alternate decisions can affect desired outcomes. In the future, these types of simulations might merge to create even more intelligent instructional simulation systems. Such simulations could provide a rich level of fidelity along with sufficient instructional support, and include some degree of artificial intelligence that can adapt the fidelity, difficulty, and support to an individual learner's needs.

This book provides a unique and truly comprehensive perspective on the intelligent use of simulations in various fields of learning and education. The book explores the learning impact of students when constructing models of complex systems and using simulations in the context of complex problem solving. According to Landriscina's theory, students should be involved increasingly in building their own models and engaging at a deep conceptual level of understanding of the content, processes, and problem solving of the taks to be accomplished. Indeed, a simulation is nothing else than a computer program that attempts to simulate the reality by operating with an abstract model of a particular physical or social system and its characteristics in order to gain insight in the functioning of the system. Every model is constructed in accordance with specific intentions in order to simplify its original in several respects as well as to create subjective plausibility with regard to the world.

The core of each computer simulation consists of a (conceptual) model of the system to be modelled and no simulation can be better than the underlying model. In addition to the model of the system a simulation program must also include a model for reasoning in order to simulate the transformations of the system. Then, a simulation can be used to show the possible real effects of alternative conditions and courses of action. In other words: A simulation is a computerized version of the model of a system that runs over time and is iterative by nature with regard to the underlying model: A model of the system must be constructed, then the computer program simulates the model, learns from the simulation, revises the model, and continues the iterations until an adequate level of understanding is developed. The conceptual model is the focal point of each simulation. All activities either converge upon or emanate from the conceptual model. All structures, through mappings either into or out of the conceptual model, must be to some extent compatible with it. This book describes all these processes in full detail and on a solid theoretical foundation.

Simulations and models are increasingly considered to be innovative learning environments which are consistent with how people learn: Variables can be limited to a manageable level and structure and direction for learning can be provided, real-world problems can be addressed, and students can take control and responsibility for their own learning progress.

Instructional researchers apply computer simulations in order to create "synthetic learning environments" for instructional purposes. That is to say, a particular task simulation has been designed to model some specific domain of reality with which students can interact. From an instructional point of view it is necessary to state that the particular model of the reality that constitutes the core and scope of the simulation represents both the subject matter as well as the "conceptual models" of a subject. A simulation is a method of teaching/learning or evaluating learning of curricular content that is based on an actual situation. The simulation, designed to replicate a real-life situation as closely as desired, has students assume roles as they analyze data, make decisions, and solve the problems inherent in the situation. As the simulation proceeds, students respond to the changes within the situation by studying the consequences of their decisions and subsequent actions and predicting future problems/solutions. During the simulation, students perform tasks that enable them to learn or have their learning evaluated. A well-designed simulation simplifies a real world system while heightening awareness of the complexity of that system. Students can participate in the simplified system and learn how the real system operates without spending the days, weeks, or years it would take to undergo this experience in the real world.

Thus, a learning environment which contains computer simulation facilities may support knowledge acquisition as well as problem solving. Actually, learning initiated by computer simulation involves explorative thinking, inductive, and analogical reasoning. These skills put high cognitive and metacognitive demands on students, who must generate hypotheses and test them by accomplishing learning tasks actively as well as performing experiments in the simulated environment. Accordingly, simulations of complex environments often require complex problem solving, which can be trained systematically by situating simulations and modeld-centered learning into the various field of instruction. Actually, this book is a great contribution to the infusion of simulations into the field of learning – it's a milestone of educational technology research and development.

Norbert M. Seel
September, 2012