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Simulation and Learning: A Model-Centered Approach

(Book Review)

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Simulation and Learning: A Model-Centered Approach
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Simulation and Learning: A Model-Centered Approach' provides a comprehensive and state-of-the-art review on the nature of simulation from cognitive and technological perspectives as well as suggests practical implications for effective integration of simulation into learning and instruction. The theory of mental models functions as the theoretical foundation, using a wide range of mental model research such as Stachowiak's neo-pragmatic and Johnson-Liard's cognitive-constructivist approaches as well as Seel's model-centered learning concept. Key topics covered by the author include foundations of simulation, simulation-based learning, dynamic systems modeling, and simulation-based instruction.

As more and more simulations are being implemented for very specific purposes, classification systems for simulation are scarce and different theoretical concepts provide diverse explanations of cognitive processes regarding simulation. Still, educational training programs using simulation have been successfully applied in the fields of flight training, health care education, dental education, command and control training of large incidents, team-based decision making, simulations for the training of firefighters, teacher training, and many other domains. However, comprehensive frameworks linking cognitive processes, learning, instruction, and simulation are scarce.

The significance of this monograph is the emphasis on the learners' cognitive functions and their link to the computer-based application while learning with simulation. This perspective is rare within the well-established research on simulation in educational contexts and adds an important conceptual view to mental model theory. Besides computer-based modelling and simulation tools for the *construction* of models, there are also tools which focus on the *exploration* of the underlying model. This second type of computer-based modelling tools for the exploration of underlying models may be differentiated further into (1) black-box and (2) glass-box systems. In a *black-box simulation* all computations are hidden from the learner. Such systems include adjustable parameters and a large variety of process visualizations which become available after the actual action of the simulation is completed. On the other hand, *glass-box simulations* expose the underlying mathematical and logical simulation model. This can be realized by revealing the underlying equations, connections, and interdependencies between variables and changing variables, parameters, or equations. Based on this important conceptual view of simulation and cognitive processes, the author offers implications for the design, development, and implementation of simulation in formal learning contexts.

The book is divided into seven chapters. Chapter 1, entitled 'An Introduction to Simulation for Learning', introduces the reader to simulation for learning. The chapter offers a critical review of the epistemic status of simulation, provides multiple definitions of simulation, and examines the relationship between simulation and learning. Finally, the chapter suggests the need for a multidisciplinary approach when investigating the potentials of simulation for learning. Chapter 2, entitled 'Simulation and Cognition', presents an overview of cognitive theories which use simulation as a metaphor for cognitive processing. The theory of mental models is used for explaining the complex functions of information processing and its internal and external representations. Chapter 3, entitled 'Models Everywhere', investigates the epistemic role of models and the various types of representation of a (cognitive) system. A taxonomy of models suggests numerous types of models, such as, physical, visual, linguistic, and electrical models. Chapter 4, entitled 'Simulation Modeling', claims that the fundamental requirement of a simulation is a model, of a real or imagined system. Detailed examples regarding the modeling and simulation process as well as applications from dynamical systems modeling, continuum physics modeling, molecular

dynamics, compartmental models, agent-based modeling, system dynamics, as well as cellular modeling and simulation are explained and contrasted. Chapter 5, entitled 'Simulation-Based Learning', provides examples how people learn with simulations. Again, the underlying cognitive processes of simulation-based learning are illustrated using examples from various disciplines. Additionally, a comprehensive view on model-based learning and teaching as well as links to cognitive load theory and instructional design is provided in the concluding sections. Chapter 6, entitled 'Simulations for Thinking', examines the relation between mental simulation and computer-based simulation. Similarities and differences of these types of simulation are discussed. The argument is built mainly around cognitive partnering, analogical thinking, as well as simulation and language. Chapter 7, entitled 'Simulation-Based Instruction', highlights how simulation can be applied for teaching. Examples are drawn from cross-curricular learning environments and provide the reader a rich collection of practical examples for teaching with simulation. The book concludes with the Epistemic Cycle, a model which describes how learners construct knowledge through simulation in a formal learning context.

The Appendix includes a well-established collection of 'Simulation Resources' for equation-based modeling, molecular dynamics, epidemiological modeling, agent-based modeling, system dynamics, cellular modeling and simulation, as well as systems modeling and design. The collection of over 35 resources includes the name of the application as well as a corresponding link.

One of the main strengths of this book are the numerous examples of well-designed learning environments using simulation. However, authentic tasks for simulation are required that enable the learners to explore the environment in dynamic interaction with the context as if they were really present. Furthermore, a stronger emphasis on embedded supports and scaffolds could be provided to the reader, as these pedagogical interventions assist novice and expert problem solvers in operating within the simulation learning environment.

Overall, ‚Simulation and Learning: A Model-Centered Approach' provides a rare theoretical perspective on simulation and cognitive processes. Additionally, it offers many good models from educational practice in various subject domains. The book is easy to follow as the many examples provide practical insights into instructional design with simulation. In this respect, it caters different expectations of educational technologists, instructional designers, and course facilitators with regard to finding theoretical understanding of simulation as well as implementing simulation into formal learning context.