Chapter 2
Computer-Supported Imagination:
The Interplay Between Computer and Mental Simulation in Understanding Scientific Concepts

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ABSTRACT

The purpose of this chapter is to explore some conceptual and methodological issues related to computer-based simulation as a teaching and learning method for STEM education. Two major themes will be examined in detail: 1) the barriers to the penetration of simulation into school programs; 2) simulation as a way to enhance scientific imagination in students. It is argued that scientific imagination is linked closely with mental simulation, a fundamental capacity of the human brain which allows us to move from static to dynamic mental representations. The role of mental simulation in understanding scientific concepts is discussed and an explicit statement is provided of the relation between computer simulation and mental simulation. On these grounds, computer simulation is viewed as a tool for extending human cognition by overcoming the limits of mental simulation. Finally, the implications of these findings for designing simulation-based instructional units and conducting lessons are discussed.

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INTRODUCTION

Will polar bears survive global warming? What happened in the first moments after the Big Bang? How can we stop epidemics from spreading? What are the effects of increasing atmospheric carbon dioxide levels on agriculture in various world regions? How can we design car interiors to improve passenger crash safety? Every day scientists and engineers all over the world use computer simulation to try to answer questions like these, and the more accurate their simulations are, the more reliable their answers will be.

To this end, universities, national laboratories, and corporate research centers are investing in supercomputing facilities where the technological limits of simulation push the envelope on our current simulation capacity. To illustrate current progress in the field, consider, for example, that biologists recently managed to create a complete computer model of an entire single-celled organism and can now simulate the basic processes of cell physiology, from DNA replication to metabolic reactions (Covert, 2013). In industry, many new products are carefully simulated before manufacturing, and simulation also helps streamline the production process. Simulation as a research method has been extended to the social sciences: economists, sociologists, and anthropologists are using simulations to understand phenomena such as the onset of financial crises, the emergence of cooperation among groups, and the fall of ancient civilizations. Furthermore, simulation is a recurrent theme in many science fiction novels, movies, and video games, to the extent that it influences our conceptions of reality itself. According to Winsberg (2010), *the last part of the twentieth century has been, and the twenty-first century is likely to continue to be, the age of computer simulation* (p. 9).

The ubiquity of simulation is due to the many advantages it offers to scientists and engineers alike. Simulation allows them to view otherwise invisible phenomena, to practice without space or time constraints, to proceed by trial and error safely and cost-effectively, to verify alternative hypotheses, and to carry out actions that are unfeasible in the real world.

These same advantages suggest that simulation can be a valuable adjunct to STEM education. Think of the possibility to visualize the air flow around the wing of an airplane or oceanic currents, to be able to see the ways in which a substance's molecules react to changes in pressure or temperature, to control the flow of electrons in an electronic circuit, to study photosynthesis in a virtual laboratory, or to change the reflectance of ice and water at the North Pole. Furthermore, innovative user interfaces give students new ways to interact with simulations, such that they can actually touch intermolecular forces with haptic devices which simulate tactile feedback (Han & Black, 2011), use sensor-augmented technologies to conduct

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