Chapter 83

Why *Immersive*, *Interactive* Simulation Belongs in the Pedagogical Toolkit of "Next Generation" Science:
Facilitating Student Understanding of Complex Causal Dynamics

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ABSTRACT

Demonstration and simulation have long been integral parts of science education. These pedagogical tools are especially helpful when trying to make salient unseen or complex causal interactions, for example during a chemical titration. Understanding of complex causal mechanisms plays a critical role in science education (e.g. Grotzer & Basca, 2003; Hmelo-Silver, Marathe, & Liu, 2007; Wilensky & Resnick, 1999), but few curricula have been developed to expressly address this need (e.g. Harvard Project Zero, 2010). Innovative education technologies have allowed content designers to develop simulations that are both immersive and engaging, and which allow students to explore complex causal relationships even more deeply. In this chapter, the authors highlight various technologies that can be used to leverage complex causal understanding. Drawing upon research from both cognitive science and science education, they outline how each is designed to support student causal learning and suggest a curricular framework in which such learning technologies might optimally be used.

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INTRODUCTION

"I just don't think you're thinking about all of the possible factors" the young engineer sighed as she opened a new word processing documents to take note of what her colleague was saying. Inez and Omar, partners on a city-planning project for their local municipality, were carefully reviewing their proposed development plans. Using advanced simulation software, each had independently modeled the effect of increased industrialization on pollution levels over time, and then predicted how these events might lead to further changes in their town's economy and demographics. They didn't exactly agree on the projected outcomes.

"It's clear as day!" Omar replied. "There was a link between number of factories and crime in my ten-year model. You can't deny that! I can make predictions about future trends based on that." Shaking her head, Inez calmly replied "I just don't think it's that simple. You're saying it's a direct connection, when I don't think it is. Look, my model looked at one hundred years-worth of change, and crime values went up and down, even though the number of factories in the city was the same. I don't know…it's just not simple." In time, the two decided on a complex relationship relating industrialization to crime and population over time, and prepared their findings in a report to the city zoning board.

Later, the two were tasked with helping to gauge the impact of proposed construction in a small suburban community near the city. Residents wanted to build new houses and recreational areas such as a golf course near a popular pond. Using a sophisticated multi-user virtual environment to simulate the area, Inez and Omar, along with two other teammates, discovered a scenario in which many large fish in the pond all died in a short period of time due to an unknown cause. Dividing the work equally among the team, each member set out to collect data over time within the virtual environment. Comparing their notes and constantly revising their causal models, the team finally settled on a plausible scenario and advised the zoning board of possible hazards due to their planned construction.

When asked later to reflect upon these two project, Inez and Omar thought that they learned a lot, and that they helped them to think about problems as being more complex. They also said it was more fun than just sitting in class and listening to their teacher. Inez and Omar, you see, were eighth-grade students and had been using these simulations as part of problem-based lessons in their science class throughout the year.

The vignette above is an example of how science students can interact with virtual simulations in meaningful and contextual ways. In these examples, students worked both independently and together to collect, synthesize, and analyze data, as well as to develop and test hypotheses. Moreover, they took part in these endeavors in a curricular setting that embedded the simulations within meaningful and motivating contexts relevant to the subject matter and students. In this chapter, we outline research supporting this framing and give examples of commercial and research-driven technologies that can be used as such.

Demonstration and simulation have long been integral parts of science education. These pedagogical tools are especially helpful when trying to make salient unseen or complex interactions, for example during a chemical titration. Demonstrations allow the teacher to draw students' attention to variables that otherwise might be missed and to guide students towards the explanatory narratives of a concept. Simulations, for instance, Molecular Workbench[1] (Concord Consortium, 2004) or the PhET Simulations[2] (e.g. Wieman, Adams, & Perkins, 2008), offer models of processes that cannot be directly observed—only inferred. These thoughtfully illustrated computer simulations are designed to illuminate particular processes such

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