# Chapter 92

# Learning about Complex Systems from the Bottom Up:
## Role-Playing Together in a Participatory Simulation

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## ABSTRACT

*The topic of learning through collaborative role-playing in computer-based participatory simulations of complex systems in STEM is presented. Participatory simulations are networked classroom activities aimed at learning about complex systems. In the process of learning, students query its underlying structure and explore its spatial, temporal and mathematical patterns in various conditions. The importance of understanding complex systems is highlighted, driving the main question in this chapter: How can we design learning experiences that support students' deep learning of emergent systems? The motivations behind using participatory simulations and their various designs are described as well as some of the more central learning research, cumulating with five studies into designs for such activities in science. Based on this research, eight design principles are introduced and future research directions are proposed.*

## INTRODUCTION

Participatory simulations (hence, partSims) are networked classroom activities that immerse students in collaborative role-playing in a social experiment into complex systems. As a design for learning, students experience the system as its *entities, orchestrators* and *explorers*. They are each an *individual agentic entity* acting and interacting locally. The class itself is the investigated system made up of many such entities, where students *orchestrate experiments*. Through these experiments, they *explore emergent processes*. The unique aspects of learning with such a design lies in traversing between these three perspectives, which provides for a more robust conceptual understanding of the system. Several simulations of this type have been developed over the years, targeting the learning of systems in STEM and social systems,

approaching a wide range of topics: epidemics, evolution, bee-hives, global warming, structure of matter, traffic, topics in probability and statistics, functions, geometry, sharing resources, economic markets and more. One of the goals of this chapter is to pull out a set of design principles for such simulations, both out of previous research and out of a series of studies conducted by the author and her students. Such an abstraction of a variety of designs could light the way to further design, use in schools, pedagogical supports and research into this unique learning environment.

Complex systems are prevalent in our world, spanning several orders of magnitude. Students learn about systems in science whose micro-level entities range from sub-atomic particles, electrons, molecules, cells, individual organisms in an ecosystem, all the way up to the stars and planets that comprise our universe. Reasoning about such systems has become an essential part of STEM education (Chen & Stroup, 1993) and recently, of computational literacy (Weintrop et al., 2016). Providing students with access to learning about systems has become of vital concern.

This chapter presents participatory simulations, a design for learning about complex systems that has students role-play individual elements within a system, becoming an integral part of it. In the process, they strategize and conduct experiments, analyze and reflect upon their results. The teacher's role is central in designing the activity, connecting it with other learning taking place, eliciting students' descriptions of experiences and their ideas, supporting conversations that involve local and global perspectives of the simulation that took place, and helping students concretize experiments they would like to conduct. This design can be viewed as an extension of computer models that represent dynamic multiple entities (ABMs, or agent-based models), where some of the "computation" is shifted from the computer to people. For example, in the Dancing with Molecules partSim people role-play gas molecules (Levy et al., 2015). They determine which way and when to move. However, their speed is determined by the computer simulation based upon energy considerations. In the TrafficJams partSim (Figure 1), students drive cars (right hand interface) and decide whether to shift lanes or slow down (Levy, Rotem & Linyevsky, 2015). However, the computer simulation sets up the roads which constrain the motion and provides collective information, such as the average speed (left hand interface). For example, in the average speed plot, one can see the speed first oscillate and then take a downward dip as a traffic jam forms. On the students' computer, they can see the cars around them but not beyond. They can speed up or down and shift lanes, limited by the cars up ahead and the road itself. As a group, they can observe the teacher's computer that provides the full view of the road from a birds'-eye view, and notice how the traffic jams – high density of cars – gradually spread through the system. They can design experiments aimed at smoothing the traffic flow or speeding it up, using a variety of strategies, such as limiting the speed or the distance between cars. This distribution of computation between a group of people and the simulation provides for enough constraints from the computer so that the conceptual structure of relationships is retained and can be explored and discovered through people's actions and collaborations.

Complex systems are made up of many entities that interact among themselves. The individual actions and local interactions among these entities emerge into global behaviors (Bar-Yam, 2003; Vicsek, 2002). Global patterns are described in ways that are distinct from those used to describe the individuals. Understanding systems presents a challenge for learners as it requires a host of coordinations: between local and global perspectives, among individual elements, between static and dynamic qualities of the system. In fact, one of the more demanding coordinations involves noticing, integrating and patterning parallel processes related to several entities as they act and interact in a shared landscape. Assisting people in learning to think in parallel ways about a collection of interacting objects clearly needs a distinct set of supports.

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