Agent-based computational models to study and teach evolution

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The goal of science education should not be limited to ‘knowing about science’, rather it should include ‘learning to use science practices and tools to make sense of the world’ (Abd-El-Khalick et al., 2004; Schwarz et al., 2017). This should involve students learning disciplinary core ideas with contemporary scientific inquiry practices. However, the nature of these authentic practices is changing at a rapid pace with the incorporation of newer technological tools and research methods. For example, the incorporation of computational modeling methods and an increasing focus on complex systems thinking has significantly changed the nature of research in biology, ranging from molecular genetic networks to ecological networks (Kitano, 2002, 2017). This calls for the design of newer learning environments that effectively and authentically incorporate these research practices in school science education. Learning scientists have pointed out the disparity and have argued for the effectiveness of a computational modeling approach that allows students to engage in complex systems thinking (Wilensky & Reisman, 2006).

In this poster, I will discuss two studies that use this agent-based computational modeling approach to model complex systems. This approach involves using a software called NetLogo (Wilensky, 1999) which is designed for educational as well as research purposes. The core elements in the model are computational objects or “agents”. Each of these agents has state variables that describe its particular state, such as age, energy level, hunger, etc. The behavior of the agents is determined by the computational rules that tell each agent what to do. The rules are framed from the agent’s point of view. For example, an agent could be a goose in a flock of geese. As each agent follows these computational rules, complex patterns emerge, such as the V-shape of a flock.

The first study is about a curricular unit called GenEvo (Dabholkar & Wilensky, 2016) that I have taught twice in India and twice in the USA to middle school students. In this unit, students explore and investigate four NetLogo models and look at three organizational levels, namely molecular, organismic, population. Using these models, the students reason about emergent patterns regarding genetic regulation and natural selection.

The second study is about modeling Fisherian explanation (Fisher, 1930) regarding the evolutionary mechanism the most commonly observed 1:1 sex-ratio in most organisms. In this part, I discuss a series of multi-agent models that capture evolution of 1:1 sex-ratio as an emergent phenomenon under Fisherian assumptions and other theories related to evolution of non-Fisherian sex ratios (Hamilton, 1967). The basic Sex Ratio Equilibrium model demonstrates emergence of Fisherian sex ratios in an evolving population with the same fundamental assumptions of biparentalism and Mendelian inheritance. First two extensions of the basic model that allow systematic violation of Fisher’s assumptions, result in stable extraordinary sex ratios (Hamilton, 1967). The data from the third extended model strongly corroborates the empirical findings based on a recent theory (Licker et al., 2013) that links male-biased adult sex ratio to sex role reversal and provides predictions that can be empirically verified.

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