BEESMART: A MICROWORLD FOR SWARMING BEHAVIOR AND FOR LEARNING COMPLEX SYSTEMS CONCEPTS

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Abstract
Complex systems concepts are important to learn for both scientific and pedagogical reasons. However, research has shown that these concepts are difficult for students to learn. In this paper we present a series of microworlds called "BeeSmart" for students to engage in a constructionist learning experience through manipulating NetLogo models, discussing with peers, and co-constructing meanings of honeybees' hive-seeking behavior. Our work contributes to the literature of designing constructionist learning environments by providing an example of simulation-based microworlds that help students' learning of complex systems concepts.

Keywords *microworlds, constructionist learning environment, complex systems concepts, honeybees*

1. Introduction

Complex systems approaches have empowered researchers in a wide range of fields to address critical problems such as financial crises, global warming, and epidemics. Using complex systems approaches, researchers study phenomena of interest by looking at the relationship between individual elements in the systems and their interactions. The complex behavior of the system at the macro level emerges from elements' simple interactions at the micro level [1]. The complex systems approaches offer unique educational opportunities for imparting scientific understanding that is both concretely grounded and widely applicable across many domains [2]. However, learning complex systems concepts has empirically been proven to be difficult for students [1], [3], [4]. In this paper, we introduce BeeSmart—a series of constructionist microworlds designed to help students learn complex systems concepts through exploring how honeybees search for and decide on new hive locations. Honeybees demonstrate impressive group decision-making abilities: a swarm of ten thousand bees can accurately choose the single best hive site from dozens of potential sites available. The intelligence of bee swarms is best explained by core concepts of complex systems such as decentralized control, positive feedback, and emergence. These complex systems concepts have been creatively applied to multiple fields including crowd sourcing, management, and logistics to increase accuracy and productivity [5].

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2. BeeSmart Microworlds

Microworlds are self-contained virtual worlds that embody a phenomenon and enable exploration of aspects of that phenomenon [6]. Students explore these microworlds in order to discover the rules that govern the phenomena involved [7]. Using microworlds to teach about bee behavior is not new. Danish, Peppler, Phelps and Washington's [8] work uses a simulation-based curriculum to give young children nascent ideas about complex systems by letting them explore bees' foraging behaviors. BeeSmart is designed for high school and university students to construct deep understandings of the aforementioned core concepts of complex systems through a scientific inquiry process.

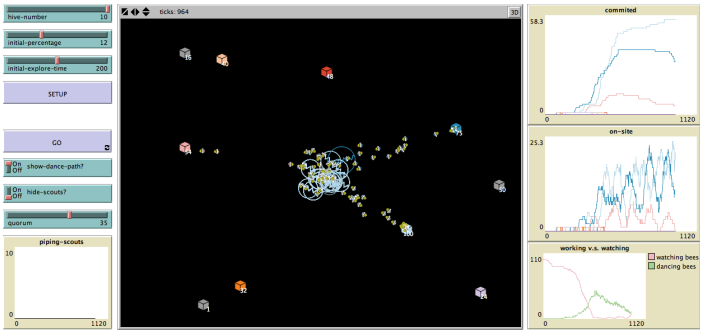

Figure 1. Schematic model

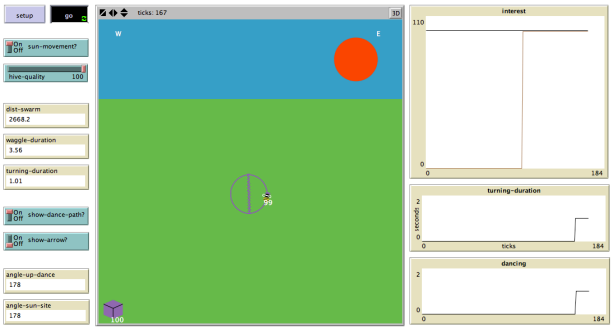

Figure 2. Waggle Dance model

BeeSmart consists of four NetLogo-based [9] models, with the first being a schematic model (Figure 1), in which students can observe the complete process of honeybees' hive-seeking and decision-making. The schematic model is then broken down into three submodels, each functioning as a microworld to help students focus on different aspects of the phenomenon and to learn the target concepts progressively. Students can explore the exact meaning of a bee's waggle dance in the Waggle Dance model (Figure 2), compare the trade-offs of bees' different communication strategies in the Multiple Check model, and experiment on different quorums of bees' "voting" for the best hive in the Debate model. Students can also go back and forth between the models, bringing their findings from one microworld to another to make sense of the whole phenomenon.

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