Scaffolding to support learning of ecology in simulation environments

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Abstract. This paper presents a semi-clinical interview-based empirical study for identifying effective scaffolds to support inquiry learning in a Multi-Agent based simulation of a desert ecosystem. Our preliminary results based on Sherin et al.'s Δ-shift framework show that all five categories of identified scaffolds contributed to students' conceptual shifts and overall learning gains. This paper lays the foundation for future research on designing scaffolds in multi-agent, simulation-based learning environments for study of ecological processes.

Keywords: Inquiry Learning, Simulation-based Learning, Scaffolding, Multi-Agent Simulations, Conceptual Change

1 Introduction

Students at all levels perceive ecology as a difficult subject to learn – in particular the concepts of population and population frequencies, organization in an ecosystem, and the relationship between individuals, populations and species [3][5]. Multi-Agent-Based-Models (MABMs) have been successful in teaching ecological concepts to novices [4][5]. Rather than describing relationships between properties of populations, MABMs require students to focus on individuals and their interactions [4], thereby engaging in intuitive "agent-level thinking" (i.e., thinking about the actions and behavior of individual actors in the ecosystem). In this paper, our emphasis is on scaffolding in MABM-based learning environments, a topic that has received significantly less attention, but is essential to support novice learning [1][2].

Scaffolding is particularly important in inquiry based learning environments where learners tend to face a multitude of problems ranging from generating hypotheses, setting up experiments, to interpreting simulation results for inferring the underlying models [1]. Quintana et al. describe a set of scaffolding guidelines and strategies organized around the three primary components of scientific inquiry: sense making, process management, and articulation and reflection [1]. Building on Quintana et al, we identify categories of scaffolds to help middle school students learn about the interactions between entities in an ecosystem. We analyze the effectiveness of our scaffolds using Sherin et al.'s Δ-shift framework [2]. A scaffolding analysis in this framework is defined as a comparison of an unassisted situation S_{base} and a scaffolded situation S_{scaf}. Δs, the difference between S_{scaf} and S_{base}, can be provided by teachers, software agents, and other tools. The change in performance (P) due to Δs is calculated as $\Delta p = P_{scaf} - P_{base}$. P_{target} is defined as an idealized target performance, and the goal of the scaffold Δs is to make P_{scaf} match P_{target}.

2 Method

The model used for this study (Figure 1) was a Netlogo based simulation [4] of a Saguaran desert ecosystem containing five species: two plants (ironwood trees and cacti), their fruits (pods) and seeds, and three animals (rats, doves and hawks). The five species are characterized by sets of simple rules that define their behavior and their interactions with other species in the environment. Besides the simulation, a set of graphs display the aggregate population for each species over time. Learners manipulate a set of sliders to regulate the initial number of each species, and they can start, stop or regulate the speed of a simulation run at any point.

We report an interview-based study conducted with 7th and 8th grade students (n = 10 in each grade), uniformly distributed by achievement profile. The experimenter conducted semi-clinical interviews with each student by periodically asking students for mechanistic explanations of their observations and predictions. Additionally, she also verbally guided dialog segments to scaffold students' reasoning, wherever necessary, to address their difficulties. Each interview lasted about 35 minutes, and was video-recorded and later transcribed for analysis.

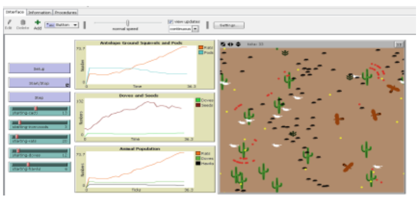

Fig. 1. The user interface (UI) of the Saguaran desert ecosystem simulation environment

3 Results and Conclusion

The five categories of scaffolds we identified to help students overcome difficulties are described below (The numbers in parentheses indicate the number of students who needed the type of scaffold): *S1. Scaffolds for setting up a simulation run* (18) through prompts for choosing initial population parameters, regulating the speed of the simulation, deciding how long to observe, which set of species to observe, etc; *S2. Scaffolds for interpreting results of a simulation run* by prompting to notice the plotted graphs, relating them with the simulation window, and drawing conclusions about the interrelatedness of the species involved; *S3. Scaffolds for controlling variables and planning the construction of the underlying model of the simulation* by suggesting a vary-one-variable-at-a-time and/or vary-one-pair-at-a-time approach to study relationships between different pair of variables/species, deciding the ordering for such studies, and keeping track of which pairs have been studied and what relationships have been found; *S4. Scaffolds through self-explanations and* *predictions (20)* by posing general and directed queries and asking the student to make predictions about simulation results; *S5. Scaffolding by creating cognitive conflict* (20) by reminding students about previous contradictory findings or statements made, or by making them re-run simulations with different parameters.

Most students required a combination of scaffolds to interpret and understand the relations between the species modeled in the simulation. The change in performance due to Δs (S1 though S5) is $\Delta p = P_{scaf} - P_{base}$, where P_{base} and P_{scaf} describe performances at the 'Initial Ideas' phase and at the end of the scaffolding phase, respectively. Initially, only general scaffolds S3 and S4 were provided which were independent of the relations being scaffolded. The performance at this stage is referred to as $P_{intermediate}$. Later a combination of S1 through S5 was administered. It was noticed that the average number of correct relationships contained in students' responses increased from 1.4 in the 'Initial Ideas' phase to 3 in the 'Intermediate' phase and 4.8 at the end of the 'Scaffolding' phase (Δp=3.4). The effects of the scaffolds on number of students who could find each relationship have also been summarized in Table 1.

In conclusion, we have identified five categories of scaffolds required in inquiry learning involving MABMs, and shown their effectiveness using Sherin et al's Δ-shift framework [2]. As we move forward, we envision designing a learning environment using such MABM simulations along with the necessary set of scaffolds.

Table 1. Effect of scaffolds on number of students who could find each relationship

Relationship	P_{base}	$P_{intermediate}$	P_{scaf} (P_{target} = 20)
Doves eat seeds	5	12	20
Rats eat pods	5	20	20
Rats eat seeds	7	8	11
Hawks eat rats	9	14	20
Hawks eat doves	2	5	15
Doves help pollinate seeds	0	1	10

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