Scaffolding to support learning of ecology in simulation environments

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Goals of the study

This study was motivated by the fact that though Multi-Agent based model (MABM) simulations have been shown to help learn a difficult subject like ecology, interacting with them results in several difficulties for learners. Since MABMs alone cannot support learning, we study how MABMs can be coupled with different scaffolds to aid the learning process.

In particular, we aim to:

- Identify the various scaffolds required by students as they work with MABM simulations
- Study the effectiveness of employing these scaffolds

The MABM simulation environment

The Multi-Agent based NetLogo environment was used to simulate a Saguaran desert ecosystem as shown in Figure 1.

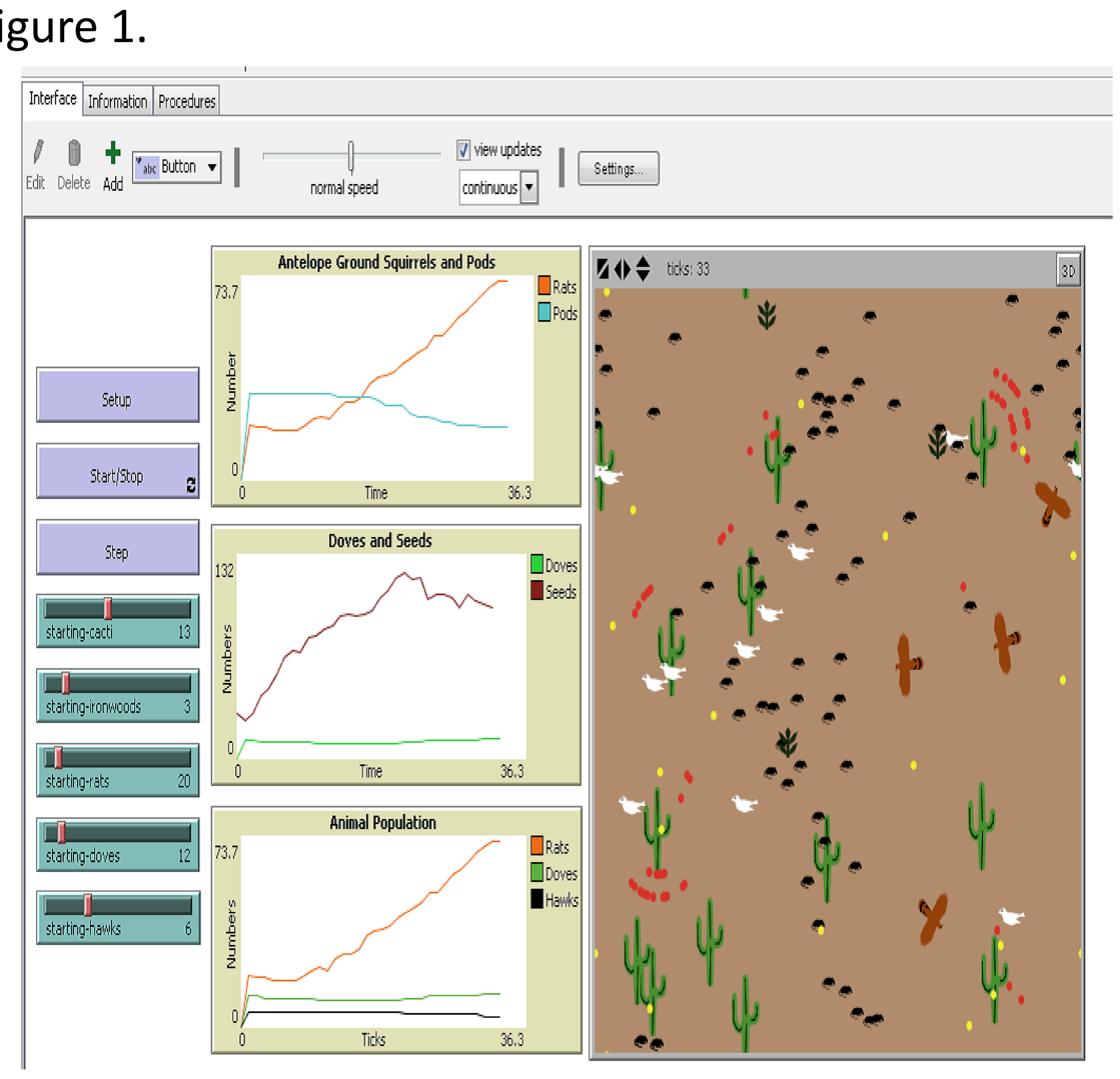

Figure 1. The user interface of the Saguaran desert ecosystem simulation environment

The primary components of the simulation are:

- The species of the ecosystem – The simulation models the Saguaran cacti, ironwood trees, doves, rats and hawks, and their interactions.
- Controls for running the simulation - Students manipulate buttons and sliders to choose the initial population values for each species, speed of the simulation, and how long they want to observe the simulation.

Learning goals for students

Learning goals for students in our study included:

- Experiencing conceptual change about important ecological processes like equilibrium, interdependence and pollination.
- Identifying the 6 inter-species relationships defining the model underlying the simulation – This was considered as the target performance (P_{target}=6) and accordingly, the performances without and with scaffolding (P_{base} and P_{scaf}) were calculated.
- Reasoning causally using the relationships discovered.

The Study Design

We conducted interviews with ten 7th graders and ten 8th graders who were uniformly distributed by achievement profiles. The experimenter worked one-on-one with each student for a single session lasting about 35 minutes.

Each interview consisted of 4 primary phases:

- Introduction – The experimenter went over an introductory tutorial about maneuvering the different controls of the UI
- Initial Ideas - Students explained their thoughts about existent relationships in the ecosystem after running the simulation a few times. These responses were collected prior to any form of scaffolding by the interviewer .
- Scaffolding - Students went through multiple iterations of prediction, running the simulation and explaining the results, and were provided with scaffolds wherever necessary. Scaffolds helped students to systematically study and discover the relationships between the species.
- Model Building - At the end of the interview, using pencil and paper, students represented the relationships they had found from their interactions with the simulation.

Types of scaffolds required

We identified the following 5 categories of scaffolds to help students overcome difficulties: (The numbers in parentheses indicate the number of students who needed the type of scaffold)

- S1. *Scaffolds for setting up a simulation run* (18) – This involves help for choosing initial population parameters, regulating the speed of simulation, deciding how long to observe, which set of species to observe, etc.
- S2. *Scaffolds for interpreting results of a simulation run* (12) – This involves understanding the plotted graphs, relating them with the simulation window, and drawing conclusions about the interrelatedness of the species.
- S3. *Scaffolds for planning the construction of the underlying model of the simulation* (19) – This requires adopting 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, keeping track of which pairs have been studied and what relationships have been found.
- S4. *Scaffolds through self-explanations and predictions* (20) – This includes posing general and directed queries and asking the student to make predictions about simulation results.
- S5. *Scaffolding by creating cognitive conflict* (20) – This involves reminding students about previous contradictory findings or statements made, or making them re-run simulations with different parameters.

Effectiveness of the scaffolds

The effectiveness of the scaffolds were evaluated using Sherin et al.'s Δ-shift framework. According to this framework,

- P_{base} is the performance at the 'Initial Ideas' phase
- P_{scaf} is the performance at the end of the scaffolding phase
- P_{target} is the target performance which P_{scaf} tries to equal
- $P_{intermediate}$ is the performance when only general scaffolds S3 and S4 are provided (General scaffolds are those which are independent of the relationships being scaffolded).
- $\Delta p = P_{scaf} - P_{base}$

The scaffolds were highly effective and the number of students who could find each relationship increased considerably, as seen in Table 1. The average number of correct relationships contained in students' responses increased considerably (Δp=3.4) and the effects were similar across grades and achievement profiles, as seen in Table 2.

Table 1.Effects 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

Table 2. Effectiveness of scaffolds by grade and achievement profile

		7th grade	8th grade	Low achievers	High Achievers	All students
Average number of correct relationships identified	P_{base}	1.2 s.d.=0.79	1.6 s.d.=0.7	1.3 s.d.=0.82	1.5 s.d.=0.71	1.4 s.d.=0.75
	$P_{intermediate}$	2.9 s.d.=0.81	3.1 s.d.=0.74	3.2 s.d.=0.86	2.8 s.d.=0.7	3.0 s.d.=0.79
	P_{scaf} (P_{target}=6)	4.6 s.d.=0.84	5.0 s.d.=0.82	4.9 s.d.=0.99	4.7 s.d.=0.67	4.8 s.d.=0.83
	Δp	3.4	3.4	3.6	3.2	3.4

Future Directions

As we move forward with this work, we envision:

- Designing an Intelligent Learning Environment using such MABM simulations along with the necessary set of scaffolds.
- Studying relative effectiveness of different scaffolds when provided by humans as opposed to software tools.