Learning about Populations in Ecosystems by "Building Them From Inside" with NetLogo: A Constructionist Approach for Teaching Population Ecology's Principles.

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Abstract
Many researchers and educators are using NetLogo nowadays in order to simulate ecosystems' behavior, both for research and for educational purposes. This paper focuses on the educational aspect of NetLogo's use, in order to teach undergraduate students, basic principles of ecosystems' comportment. The students have as a key-characteristic that their background in Science is limited, and that they are prospective school teachers, at various educational levels. The new idea presented in this research, is that the learner tries, being taught by use of NetLogo models, to conceptualise each agent's ("turtle's") behavior, as well as their collective behavior. This is achieved, avoiding by any means to teach NetLogo programming, even at introductory level. Apart from that, the undergraduate students navigate in a menu, making some specific choices

about how the agents will behave, thus – in a way – they "build" the modeled ecosystem's behavior. The Constructionist objective is – for the learners – to build a NetLogo-modeled ecosystem, which performs optimally, under certain demands. A participatory-simulation-based instruction of this kind is believed to have good learning outcomes and this is investigated by interviews to a sample of students.

Keywords: Agents, Constructionism, Ecology, NetLogo, Teaching, Interactive Simulation.

1. Introduction

NetLogo [1] is a multi-agent modeling and simulation environment, as well as a programming language, of the Logo family [2]. It is used both for research purposes, in order to model the behavior of systems under study [3] – especially Complex systems – and for educational purposes, in order for the students to learn about natural systems, showing collective behavior [4]. In this study, NetLogo is used as an educational tool only, and specially in the context of teaching and learning about ecosystems. Many researchers and educators have been using NetLogo in order to model ecosystems [5] and more specifically in order *to teach* people about ecosystems' specific properties and behavior [6]-[8]. The difference of the current approach lies in that: All the educational researchers using NetLogo to teach about natural systems, have been using it to teach, either as a simulation environment combined with worksheets [9]-[11] or they have previously taught their learners basic things about NetLogo programming, and then have used it as an instructional tool [12], [13]. In our project, the student "builds" a new artifact: *a NetLogo model performing optimally under the specifications set to it*. He/she simultaneously learns through building the model, in accordance with the basic principles of Constructionism [14], [15] but with no necessity of NetLogo programming, when creating the models. This is done by "menu" selections (buttons) mainly, or by oral answers. Of course, the interaction with the models (sliders, switches and buttons being able to move) definitely remains a key-feature of learning, since the models used here are simple NetLogo models, existing already – in a similar form – in previous Logo-like environments, like StarLogo [16].

The overall teaching and learning environment here, resembles Wilensky's participatory simulations with the use of "HubNet" [17], [18] but does not require such heavy technological equipment, since the latter does not exist in most Greek computer classrooms.

2. Sample and Method

The "selection menus", as well as the NetLogo models, were tested to a sample of 17 students of the department of Primary Education, University of Athens, Greece. The students had been following the optional (but pre-requisite for some fields) topic: "Science and Environment: The Laboratory Approach", during the fall semester of 2012-2013. The 17 students were sitting in front of a PC in pairs – or the last three in a triad – and *were interviewed from the first of the authors for about one hour and a half*. The interviews were semi – structured interviews, and were conducted both with the use of worksheets and with the use of the PC, where the appropriate NetLogo Models were installed. Each student was giving oral answers recorded by the researcher in a digital recorder and was also completing some answers on the worksheet. There were also intervening "PowerPoint-like" slides – with menus – on the screen, where the students made – each time – specific "choices" from "menu" buttons and decided what the "behavior" of the agent(s) should be in the next execution of the model.
The NetLogo model that was the basis of the section of the research presented here, was *"Wolf Sheep Predation"* [19], from the Models' Library of NetLogo, as well as its – more mathematical – counter-part : "Wolf Sheep Predation (docked)" [20], again from the Models' Library. This latter model comes together with another teaching tool of NetLogo, the "System Dynamics' Modeler" [21], which will also be used. Screenshots of the two models – "Wolf Sheep Predation" and "Wolf Sheep Predation (docked)" – as well as the System Dynamics' Modeler of the second model are respectively depicted in Figures 1, 2 and 3 of the paper.

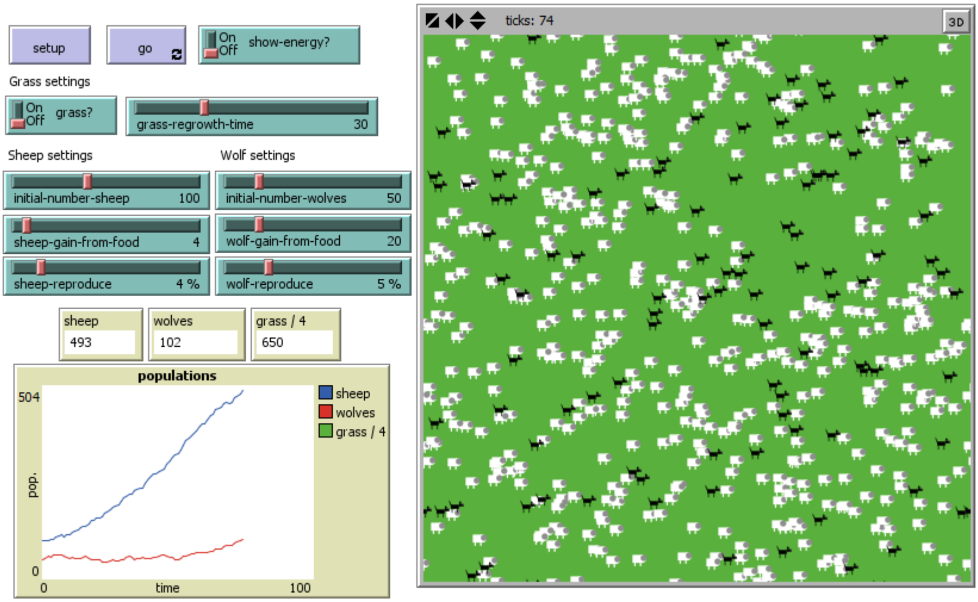

Figure 1: A screenshot of the NetLogo Model "Wolf Sheep Predation".

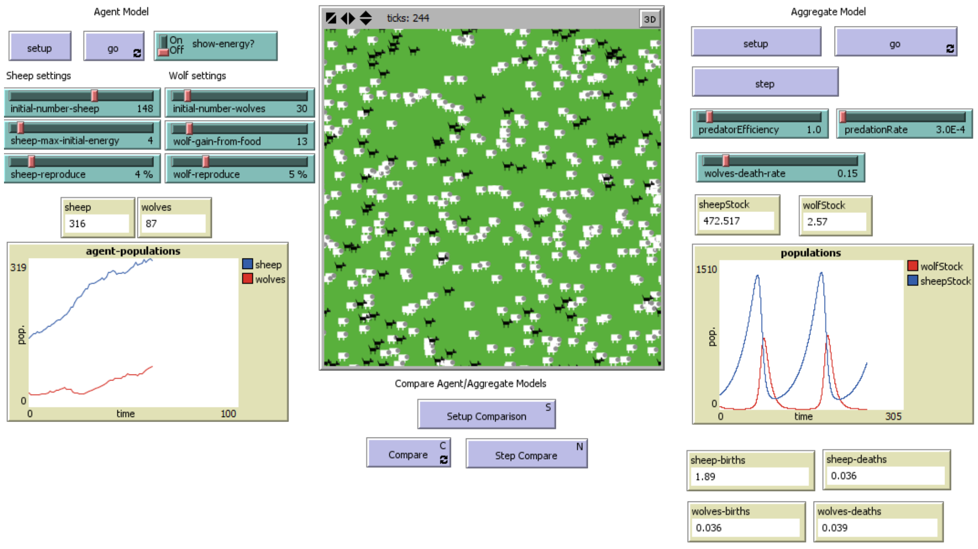

Figure 2: A screenshot of the NetLogo Model "Wolf Sheep Predation (docked)".

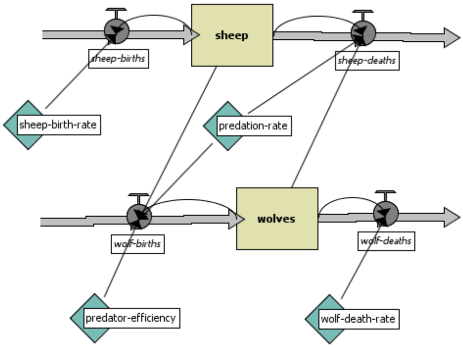

Figure 3: The System Dynamics' Modeler of NetLogo for the Model "Wolf Sheep Predation (docked)"

[*In the rest of this work, the initials WSP refer to the Model: "Wolf Sheep Predation", the initials WSP(d) refer to the Model: "Wolf Sheep Predation (docked)" and the initials WSP(d)-SD refer to the "System Dynamics' Modeler" of the Model "Wolf Sheep Predation (docked)"]*.

By using these NetLogo models and the selections' menus (with buttons) as well as by performing the interviews with the students, *three* research questions were attempted to be answered:

a. Can the students understand the rules (the algorithm) followed by each agent (e.g. by the "wolves" or by the "sheep") on the model-screen? If yes, to what extend?

b. Are the specific variations of the model – created by the authors – able to make the students better understand the behavior of agents?

c. If the students can define certain things in the comportment of the agents, *through selection buttons and not through programming*, can they create a Constructionist artifact, i.e. *a model of populations performing optimally according to certain specifications*? If this is possible, then to what extend does this help them learn things about the modeled ecosystems and populations?

The interviews were, as already said, semi-structured, so here only the basic questions in them are presented. The first stage of the interview referred to the model WSP and the students were asked specific questions about conceptualising the agents' behavior:

Q-WSP1: “What do you think the exact algorithm followed by one “wolf”, as it moves through the patches is”?
Q-WSP2: “What do you think the exact algorithm followed by one “sheep”, as it moves through the patches is”?
Q-WSP3: “What do you think is the difference between the situation where the “GRASS” is “On” and the situation where the “GRASS” is “Off”?
After these introductory questions, the interviewees were introduced to the notion of “stability” and “instability” in the ecosystem. [22]. “Instability” means roughly that one or more of the ecosystem populations gets extinct (or – more rarely – increases dramatically) whereas “stability” refers to the situation where all the populations remain in the ecosystem, even with oscillations on their size.

The next set of key-questions was:
Q-WSP4: “Can you find exact combinations of the system parameters (expressed by sliders, switches etc) with which the system *tends to be stable*? If yes, could you describe them?”.
Q-WSP5: “Can you find exact combinations of the system parameters (expressed by sliders, switches etc) with which the system *tends to be unstable*? If yes, could you describe them, again?”.

Now the Constructionist objective was set:
The students were asked to “build on screen” a specific two-population (or three-population when the grass plays role) ecosystem, which is *stable in most executions of the model*. We asked them to build this situation in two different ways:

(a) By choosing – after lots of trial-and-error, which is typical in Constructionism [23] – specific values for the parameters of the NetLogo Wolf Sheep Predation model.
(b) By making suggestions on what the algorithms followed by the “animals” and by the “grass” should be, *in order for the population system to be stable, in a vast range of combinations of parameter values!*

Referring to case (b), some of the students selections were able to be depicted in an interface-like button menu, and the student could see the actual variation of NetLogo model WSP, running on screen, according to the button he/she chooses to press (a hyperlink) ! An example of such a menu is depicted in Figure 4.

. Two kinds of sheep exist, which have different predation rates by the wolf.

The wolf is also predated by something, e.g. by "hunters".

The wolf, when having eaten a sheep, goes on in the same direction, not randomly, to the following patch

There are "shelters" for the sheep, i.e. areas within the micro-world, where the sheep cannot be predated by the wolves.

Figure 4: A picture of the "button menu" presented to the undergraduate students.

In Figure 5, such a case is presented, where there are two "kinds (species) of sheep" with very different predation rate by the wolf and also "shelters" (two buttons are selected and pressed).

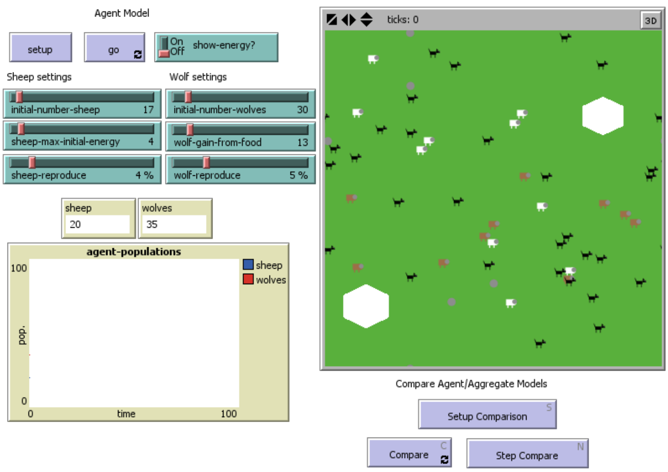

Figure 5: The “Wolf Sheep Predation” model with two “species of sheep” and also with “shelters” (two of the menu buttons are selected and pressed).

Afterwards, always in case (b), the students were asked:

Q-WSP6: “Did your selection of buttons and the respective behavior of the model actually led to a more *stable, generally, ecosystem*? Why, do you think this happened, or not?”
There were two final questions in the interview, concerning the model “Wolf Sheep Predation (docked)”
WSP(d)-1: “What do you think is the difference between the left part (“Agent Model”) and the right part (“Aggregate Model”) of the interface screen in this model”?
WSP(d)-2: “Can the right part of the screen reach both stable and unstable situations? Try it. What is the reason, in your opinion?”

3. Results and Discussion

All the answers of the students were grouped, as regards their conceptual content, in certain categories.

In Q-WSP1 AND Q-WSP2:
5 out of the 17 students: failed totally to find the algorithm followed either by the “wolf” or by the “sheep”.
8 students: found *only* the algorithm followed by the “wolf”
4 students: found *only* the algorithm followed by “sheep”

In Q-WSP3
10 out of the 17 students of the sample gave the “scientifically correct” answer, that when the grass is “on”, it can also be eaten and there may be deaths due to lack of it, too
5 out of the 17 students of the sample gave the opposite to the “scientifically correct” answer, that when the grass is “on”, there is always plenty of it – it never exhausted.
2 of the students: gave other irrelevant or incorrect descriptions.

It was concluded by this set of results, that the students were able, even at a limited majority, to *conceptualise the behaviour* of the NetLogo agents, by interacting with the model.

In questions Q-WSP4 and Q-WSP5:
6 answers out of 17 students: managed to find situations where the system tends to be stable.
9 answers out of the 17 students managed to find situations where the system tends to be unstable.
6 students resulted in stable situations, but did not make it with unstable ones.
13 students resulted in unstable situations, but did not make it with stable ones.

* [Obviously, the results here do not sum up to 17, since there is variety of combinations].
Finally, after having made choices from the "menu" with buttons, it has at first to be mentioned that;
9 of the students made suggestions that were actually present in the buttons' menu.
5 of the students made suggestions that did not exist in the buttons' menu.
3 of the students did not manage to make any suggestions at all.

And then, passing to Q-WSP6:
10 out of the 17 students gave "correct" scientific explanations, about why their suggestion led to a stable model, as they expected.
8 out of the 17 students gave "correct" scientific explanations, about why their suggestion did not lead to a stable model, contrary to their expectations.
4 students could not see why their suggestions failed.
* [Again here, the results here do not sum up to 17, since there are variety of combinations].

Discussing the results of the interaction with the button menu, as well as the outcomes of question 6, it is apparent that the ability to "define" things in the model, without programming, gives relatively good "overview" to the learner of the model's behavior and helps him/her to an extent, predict the model's outcome.

As regards the questions referring to the “Wolf Sheep Predation (docked)” model:

In WSP(d)-1:

7 out of 17 students realized that in the left part of the interface, “randomness” or “chance” (whether the wolf actually runs onto a sheep or not) plays an important role, whereas in the right part of the screen only mathematical equations define the evolution of the populations.

6 students failed to realize any difference between the two parts.

4 students were not able to answer at all.

In WSP(d)-2:

11 of the 17 students realized that in the right part of the interface, *population stability* is the usual outcome, whereas in the left part this is not the case.

4 students saw equal possibilities of stability and instability in both sides of the screen.

2 students could not answer.

Again in the Constructionist objective given to them for this model:
“build a *stable ecosystem* in the left part of the screen (“aggregate model”)
10 out of 17 failed, which is well justified.
Discussing the results for the “Wolf Sheep Predation (docked)” model, it becomes apparent that the extensive interaction with the model, combined with a Constructionist objective for the students, helps them learn basic principles of population ecology.

4. Conclusions

Within the current work – part of a broader research that lead to a PhD, about the educational use of NetLogo for teaching systems in Nature and specifically ecosystems as Complex Systems – it became evident:
a. that through interaction with the models, the students can conceptualise natural and environmental systems’ principles. Especially by constructing Multi-Agent-based models from “the inside”, the learners are lead to

understand the behavior of agents, without being introduced to computer programming, and

b. The learners are eventually more capable of building models of natural systems and ecosystems, not totally, but by deciding part of the behavior of agents, a skill that is crucial for understanding how the modeled systems will behave under different rules.

By the activities described above and by the results obtained, it seems reasonable to assume that the above aims are a bit fulfilled.

It is also concluded, from this little case study with the use of interviews, that students might possibly, through the use of simple NetLogo models and their variations, as well as through their navigation in specifically created interfaces, learn how to *act and "think" like members* of a natural system or ecosystem and thus understand its functions and behavior. The models are, thus, built step-by-step through intercourse with the learner, and this gives him – it is believed – further insight on the functioning and modeling of ecosystems.

The next step of research is now to make the student move and decide "as one single agent" and then altogether they see their overall performance as a natural (eco) system. This can be achieved if, as we do now, network the computers in a common server-screen, and use tactics similar to Wilensky's "HubNet" [16], [17] but with less equipment and more in a "dialogue-form" with the learner.

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