USING DYNALEARN IN A LEARNING BY MODELING APPROACH TO TEACH ENVIRONMENTAL SYSTEMS KNOWLEDGE FOR SECONDARY SCHOOL STUDENTS

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RESUMO
Tendências atuais na educação científica mediada por computadores apontam para a importância da construção do conhecimento pelos alunos através de uma interação ativa com o ambiente de aprendizagem. Atividades de modelagem farão parte das atividades escolares regulares e contribuirão para desenvolver o raciocínio científico dos alunos. Enquanto estão envolvidos em tarefas de modelagem, os estudantes adquirem maior compreensão dos conceitos apresentados e desenvolvem outras habilidades cognitivas, explorando, construindo, utilizando e testando modelos no computador. O trabalho aqui descrito tem como objetivo apresentar os resultados de um estudo de avaliação de DynaLearn, um software que compreende um ambiente de aprendizagem que combina raciocínio qualitativo, agentes pedagógicos virtuais e tecnologia semântica (www.dynalearn.eu). Esse software foi projetado para ser usado principalmente por estudantes do ensino médio e universitários em disciplinas nas quais se adota a dinâmica de sistemas. O presente estudo explora princípios da biologia da conservação como parte de um currículo de ciências ambientais. Na atividade de avaliação com alunos de ensino médio aqui descrita, observou-se que melhorou o entendimento de conceitos do conteúdo trabalhado nas atividades de modelagem, os alunos se sentiram motivados com essas tarefas , e consideram que modelagem em DynaLearn é uma abordagem interessante para ser incorporada às atividades em sala de aula.

ABSTRACT
Current trends in computer based science education point out to the importance of knowledge construction by students through active interaction with the learning environment. Modeling will become part of regular science education classes, and will contribute to the learners' scientific reasoning. While involved in modeling tasks, learners acquire a better understanding of the concepts at hand and develop other cognitive competences, by exploring, building, using and testing computer models. The work described in this paper aims to present the results of an evaluation study of DynaLearn, a learning environment that combines qualitative reasoning, virtual pedagogical agents and semantic technology (www.dynalearn.eu). This software is intended to be used primarily by secondary school and undergraduate students in a learning by modeling context, on disciplines in which dynamic systems are studied. The present study explores principles of conservation biology, as part of a curriculum on environmental science,. After the evaluation activity run with secondary school students described in this paper, it was observed improvement in understanding of the concepts worked out in modeling activities, the students were motivated by the activities, and consider modeling in DynaLearn an interesting approach to be added to the classroom activities.

INTRODUCTION

In most countries, including Brazil, science-related carreers currently show a decline, as the amount of students taking science curricula is decreasing and many students are dropping out from science disciplines. Osborne *et al*. (2003) identify the lack of

engagement and motivation in science teaching as one key problem. In order to solve these problems policymakers and other stakeholders are doing a great effort to accomplish effective science education (Eurydice, 2006), which includes the development of new curricula, learning tools and teaching strategies.
Modern learning theories describes learning as an active, internal process of constructing new understandings (Staver, 2007). The construction of deep scientific knowledge results from actively practicing science in structured learning environments. In line with these view points, learning environments should support students' active construction of knowledge (Staver, 2007).
Modeling is a central skill in scientific reasoning and provides a way of articulating knowledge (Bredeweg and Forbus, 2003). Eckleberry (2000) suggests by his review of literature that system dynamics and computer modeling software technology could be a beneficial innovation for improving reading comprehension scores, especially in the area of cause-effect relationship. Having taken a balanced view of the power of modeling, a person concerned with the teaching/learning of modeling may require that we '*use modeling primarily to empower thinking and conceptualize the problem areas more clearly*'. In other words, '*Modello, ergo comprehendo*' (Kadijevich *et al*., 2005).
In computer modeling, students create their own executable external representations of a domain or subject. They can simulate the models they create and observe and draw conclusions based on the model output (Löhner *et al*., 2003). Learning to formulate, test, and revise models is a crucial aspect of understanding science, it is critical to helping students become active, lifelong learners (Bredeweg and Forbus, 2003). Qualitative modeling offers the potential for engaging younger, middle-school students in scientific modeling (Forbus *et al.*, 2004). This is because it provides a compact set of modeling elements, a formal language based on explicit representation of causality, the possibility of expressing heterogeneous, incomplete or uncertain knowledge and run simulations to express the dynamics of (physical, biological, social etc.) systems without using numerical data.
Motivated by these needs and because students typically have difficulties in understanding complex ecosystems patterns, as they do not reason or organize information the way ecologists can do (Dresner, 2008), the DynaLearn project (www.DynaLearn.eu) aims to develop an interactive learning environment that allows learners to construct their conceptual system knowledge. The work described in this paper aims to present the results of an evaluation study of DynaLearn, in a classroom, in a learning by modeling context, exploring a curriculum on environmental science and principles of conservation biology.

MATERIAL AND METHODS

Participants

The evaluation study was conducted in a public secondary school in Sobradinho, Distrito Federal, Brazil, using the school informatics lab. The 21 participants where second year students, ranging from 15 to 18 years old, and participated of a workshop conducted by the authors of this paper.

Design of Evaluation Plan

The workshop lasted 18 hours, during which expositive dialogued lectures, discussion about relevant topics based on selected texts, and modeling activities were performed. The software DynaLearn (DL) was used as a learning workbench for the students to model knowledge about dynamic systems and, this way, to understand concepts and principles of conservation biology and their implications.
Within the DL workbench a number of modeling possibilities are available for users to develop models at different levels of complexity, using different modeling primitives. It

is possible for users to build models ranging from traditional concept maps, through formalized representations of systems structures and basic notions of causal relations, up to qualitative models that utilize hierarchies of reusable knowledge fragments (Noble *et al*., 2010). DL software presents a graphical interface where it is possible to access six different modeling environments, called Learning Spaces (LS), varying the number and types of model ingredients available for modeling activities. The most basic Learning Space (LS1) allows for building conceptual maps and the most complete or complex Learning Space (LS6), to build generic and reusable models.

Modelling assignments and Evaluation instruments

During the workshop the students were asked to inspect, create and simulate qualitative models about fragmentation and devastation of the *Cerrado* biome due to agricultural expansion in LS1 (concept map) and LS2 (basic causal model); deforestation in LS3 (basic causal model with state graph); and main factors of biodiversity loss in LS4 (Causal differentiation model). To evaluate their experience with DL and modeling and reasoning about the issues explored in the workshop, we have applied 2 questionnaires of pre and post-tests (about causality – “if’ and “then” statements, and about concepts of conservation biology principles), two intermediate questionnaires about causality and identification of modeling ingredients, and two questionnaires about motivation and software usability.

We addressed concepts of environmental science curriculum to support students with lectures about QR modeling and conservation biology principles so they were able to build their own diagrammatic representation of relevant aspects through QR ontology and learning spaces in DL. This construction process involved the representation of the main aspects of biodiversity protection, strategies and sustainable actions to avoid biodiversity loss. Students should be able to identify, during the course, the main threats to the global biodiversity. We have evaluated either the students’ interaction with DL learning spaces, the motivational aspects of software usage and also we investigated students’ understanding about cause and effect relations, and the skill of building diagrammatic representations over modeling activities.

During the meetings

First we applied one test about causality relations using the following text: “The hydrological erosion environmental problem” where the students should identify the cause-effect relations; and a pre and post-test as in Table 1. After answering the evaluation instruments, the students built a concept map about ‘Habitat Fragmentation’ based on the text: ‘Agribusiness’ expansion: fragmentation and destruction of *Cerrado*’.

In the second assignment the topics addresses were: *Cerrado* destruction. This activity involved models in LS1 (concept map) to the LS2 (basic causal model). They were asked, also, to identify in the text ‘Environmentalists and woodcutters’ the main cause and effect relations. By the end they answered the questionnaire about the ‘lake’ features and to identify the quantities, the entities and the influences between quantities.

Table 1. List of questions applied in pre and post-test about conservation biology.

(1) If the global changes are continuous and inevitable, why we should care about biodiversity conservation?
(2) What are the actions that should be adopted by the human population to ensure the species conservation?
(3) What are the main threat causes to the biodiversity and the most important consequences, regarding your own opinion?

During the third lecture, the topics worked were: deforestation – main causes and consequences, how to build a model in LS3 (about lake pollution), what is causality and domino effect, modeling concepts and ingredients (quantitative space, simulation, state graph, states and transition, correspondences), how to build a model in LS3 about deforestation. We gave to students the key answer of the activity about the 'Lake' with the modeling ingredients of the previous class. After doing that they built the basic causal model in LS3 about deforestation.
In the fourth meeting the topics addressed were about DL environment, about causality, modeling concepts and primitives (direct influences and proportionalities). After the assignment, the students finished the models in LS3 that they had started during the third class. The last lecture (fifth assignment) was about the main drivers of biodiversity loss, where we presented the difference between processes and propagation of processes. The students answered an exercise in LS4, where we investigated better the students' notion about the use of modeling primitives, and also about model simulation. And to finish, we applied the post-tests about causality relations and conservation biology principles. The students answered two questionnaires about DL usability and motivational aspects. After running this evaluation, we had a general overview about how students interact with DL, what they like, in what they have difficulties and important ideas to software improvement.

RESULTS AND DISCUSSION

Conceptual Understanding

It was noted a change in the way of perceiving the content, building more elaborated and objective answers. Indeed, the paired *t* test using a bootstrapping randomization method resulted in a significant difference between pre and post-tests among students ($P < 0.00$; $t = 0.62$; $N = 8$), suggesting an improvement in their conceptual understanding.
A study performed by Salles and Bredeweg (2003) with undergraduate students found results supporting that modeling effort enhance the comprehension of ecological issues and can optimize the learning of complex systems. Other similar result was obtained in an experimental study (van Borkulo, 2009) regarding learning about global warming were compared two groups: the first group followed a traditional approach, and the second group followed an inquiry modeling approach, and the main result showed differences with respect to the complex items with better scores for the last group.

Modeling Activities

The students were able to build models about the subjects discussed in class. Initially, they expressed their understanding of the system in concept maps LS1 (Fig.1a), including much more details than they did in LS2 (Fig.1b) and LS3. In doing so, they were developing the capacity of focusing on relevant aspects of the system to model. It was observed also that the students were able to correctly express causal relations between the objects and the variables in LS2 and LS3 and to correctly identify positive and negative influences (Fig. 2).
Overall the students reported that the modeling activity was a motivating task, and agreed with the idea that modeling is an interesting approach both for teaching and learning. For some students, conceptual modeling is a totally new approach. Moreover, it was appointed by the students that this type of activity encourages a new way of thinking about the behavior of the ecological and environmental systems: "*the software is really impressive; I could see problems, which our society is facing, in a different way*".

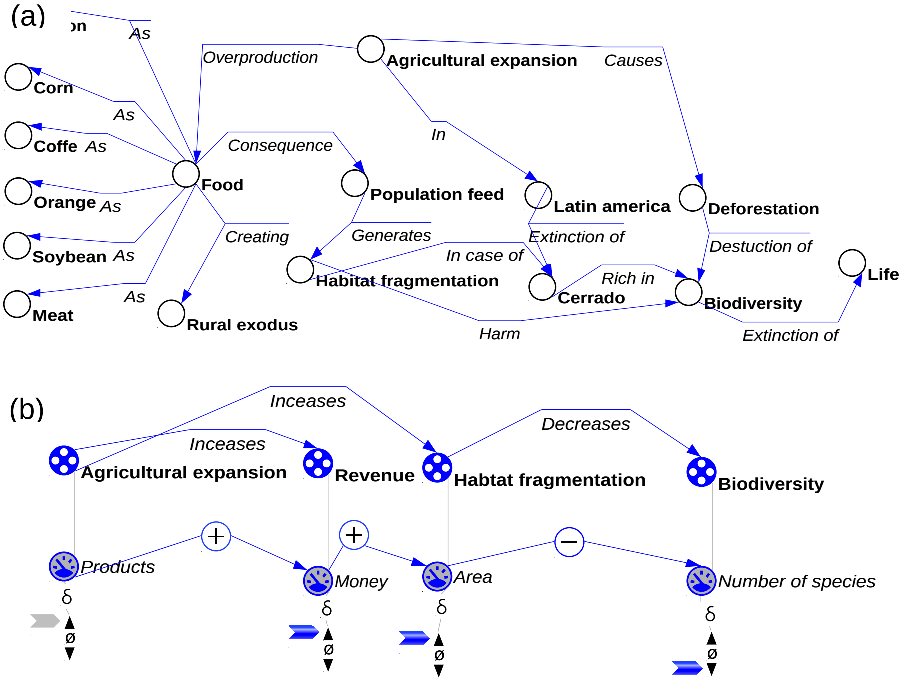

Fig. 1. Two models built by a student (a) conceptual map built in Learning Space 1 and (b) basic causal model built in Learning Space 2.

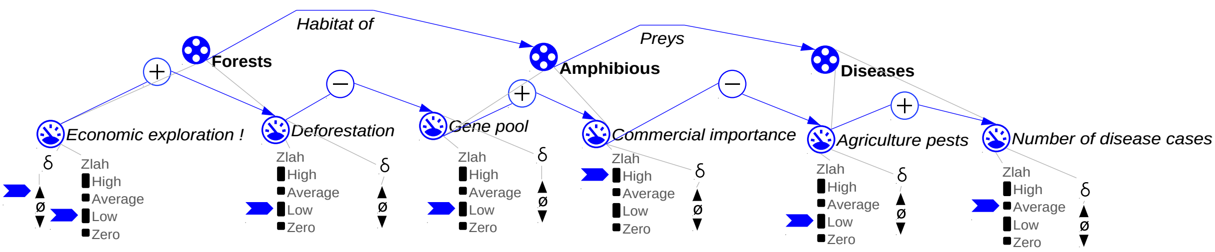

Fig. 2. Model built by a student showing positive and negative causal relations in Learning Space 3.

Students reported no major difficulties in the tasks of identifying and extracting key information from relevant texts of reference used for the model development. Also, in general they agreed that, having built models, it was easier for them to express the same concepts in written texts.
The students did not indicate great difficulty in understanding and in describing the structure and behavior of the system when transposing knowledge expressed in concept maps into basic causal models (Fig. 1). We noticed, however, greater difficulty in understanding of the differences between direct influences and qualitative proportionalities, causal dependencies that respectively represent processes, the initial cause of changes in the system, and the modeling element used to propagate the effects of processes. As observed by Bredeweg *et al*. (2007) and (Nuttle and Bouwer (2009) as students become more familiar with Qualitative Reasoning (QR) representations, they will be able to provide more correct and detailed responses and improvement in users' correct interpretation of diagrams.
In these activities, as observed by Sins *et al*. (2005), when constructing the model, students can focus on important variables and relationships and on mastering the modeling formalism without having to be concerned about the mathematical form of the relationships.

The students showed a certain facility to distinct entities from quantities, and also to link the influences between each variable. The individual differences in understanding QR ontology were visible. Some of them learnt faster how to distinguish quantities from entities and the minority presented some kind of difficulty.

The Course and the Use of the Software

Asked about the course and the experience of using the software, the students considered the learning activities very interesting and showed a favorable opinion towards DL. One of the students said "*I liked everything a lot, DL is a new way of learning; it was a little complicated in the beginning, but as time passes by, our understanding is improved by the practice*".

After exploring problems related to biodiversity conservation in DL, students said they understood these topics way better, demonstrating greater interest on the potential of DL in the learning process: "*I found this new software very interesting, because I think it would help very much learning in classroom; it is something different, and as a general rule, different things call our attention*".

Students agreed that modeling with the DL software opened up new ways of thinking about the natural systems. This argument can be found in statements like "*What I found more interesting is that, after we establish some relations, it 'thinks' for us!*". Another student "*liked that it is possible to better organize the knowledge and run simulations starting from some influences and quantities*".

CONCLUSIONS

The software can improve the conceptual understanding, and has promoted stronger ties between students and the subject matter, which facilitated and motivated them to participate in the activities proposed by the researchers, thereby learning the objects of knowledge, and hopefully developing scientific reasoning skills about the behavior of dynamic systems.

These results support the idea that learning by modeling may change the way students interact with their environment, possibly applying knowledge acquired at school and assuming a pro-active attitude towards their reality. As mentioned by one student: "Now all the polemic issues I see on the news, I feel like doing a model, even if mentally, pointing out which are the entities, quantities, causal relations… Anyway, it was very helpful!"

These results had shown the potential and the importance of the suggested approach in scientific learning with modeling activity using DynaLearn software. Further advanced research might be developed to evaluate more aspects and the potential learning tool of the DL software approach in regular classes.

ACKNOWLEDGEMENTS

We would like to thank the students, participants of the evaluation, and DynaLearn Project, co-funded by the EC within FP7, Project number 231526. For further information, visit http://www.DynaLearn.eu

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