

INFORMATION COMMUNICATION TECHNOLOGY IN SCIENCE EDUCATION: COMPUTER MODELLING ACTIVITIES BASED ON SYSTEM DYNAMICS

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ABSTRACT

Current technological advance has raised a wide debate over its integration to the educational context. Under this perspective it becomes necessary to delineate an investigation about its effective usage into classrooms. This work reports on the experience of using computer modelling as framework for infusing new technologies in the Information, Science and Technology in Science Education subject, taught to students of the Physics and Biological Sciences graduation classes. The results disclosed differences in the two students groups, both in the development of models and in the educational modules structuring, proposing new directives to attend each group specifically.

1. INTRODUCTION

The current technological advances have raised a wide debate about its transformations in communication and consequently over human resources formation. In this sense, a most needed discussion looking over the understanding of the dynamics of these transformations in the educational context comes to being, along with the development of a theoretical framework enabling these technologies integration to the pedagogical practices from specific curricular contents[1].

In this context, this article report a experience carried out within a subject offered to Physics and Biological Sciences undergraduate students at the Federal University in Espírito Santo – UFES.

2. THEORETICAL FRAMEWORK

One way to integrate Information Communication Technology – ICT – into the educational context is through the concepts of modelling and computer modelling. A model can be defined as “an intermediary between the abstractions in theory and the concrete actions of experimentation, helping to

build up predictions, investigation conduction, the justification of results and to facilitate communications”[2].

In this sense, human reasoning may be understood as being based on models. Thus three types of reasoning can be identified: *quantitative*, in which numerical relations are used to determine, through variables, the system temporal evolution[3]; *semi-quantitative*, when the emphasis is on trends of system variables [4]; *qualitative*, where the understanding of a system is promoted without using mathematical models[5].

In this way, computer modelling demands the design of an investigation including the development of modelling activities and effective usage in the classroom, to reach conclusions about its real possibilities of integration into the school[1].

3. STUDY

This work was designed and carried out within subject offered by Physics Department at UFES named “*Information, Science and Technology in Science Education*” – ISTSE – for promoting the discussion of strategies to allow the use of ICT into the teaching-learning process[6]. It was divided in theory and practical activities that included the development of projects. This paper analyses the final projects developed by the students.

4. METHODOLOGY

4.1. The subject

Over the theoretical classes, the students have participated in the exposition of thematic topics, including short-course about different computer modeling environments among then STELLA[7]-[8]. Practical activities consisted of planning, development and implementation of projects related to specific topics from Physics or Biology, articulated with the computer modelling and modelling concepts in the format of an Educational Module. The Educational Modules were developed in peer that was evaluated at the end of course.


4.2. STELLA

The modelling environment used for the projects was STELLA (*Structural Thinking Experimental Learning Laboratory with Animation*), which allows model construction setting causal relationship among the variables considered relevant classified as *stock*, *flow*, *converter* and *connector*, without working directly with mathematical equations. The students have worked with this modelling environment using the *Model Construction Process* [9]-[11].

4.3. Project Evaluation

The evaluation consisted of a questionnaire named Educational Module Evaluation Table presented in Figure 01. Ratings were on a scale of 1-5, with 5 being the most favourably reply.

Figure 01: Educational Module Evaluation Table

	Federal University of Espírito Santo Centre of Natural Sciences Department of Physics	Subject: Information, Science and Technology in Science Education - www.modelab.ufes.br/ict2004 -										
<p>Educational Module Evaluation Table</p> <p>Fill in the form with an X in the grade you think is most applicable according to the grades shown below.</p> <table style="margin: auto; border-collapse: collapse;"> <tr> <td style="border: 1px solid black; padding: 2px 5px;">1</td> <td style="border: 1px solid black; padding: 2px 5px;">2</td> <td style="border: 1px solid black; padding: 2px 5px;">3</td> <td style="border: 1px solid black; padding: 2px 5px;">4</td> <td style="border: 1px solid black; padding: 2px 5px;">5</td> </tr> <tr> <td colspan="5" style="text-align: center; padding: 2px;">Bad Good</td> </tr> </table> <p>Where you feel applicable, please write down comments and critics inside the charts.</p>			1	2	3	4	5	Bad Good				
1	2	3	4	5								
Bad Good												
Computational and Interface Aspects												
1. The Main Menu is easy and quick to be accessed?	1	2	3	4	5							
2. The buttons are easy to be understood?												
3. The buttons are well located?												
4. Is it easy to 'get in' and 'get out' in any Educational Module activity at any stage?												
5. The Educational Module is easy to be used?												
6. How do you evaluate the presentation/design of the Educational Module?												
Educational Aspects												
7. From your point of view, what are the Educational Module Objectives?												
8. The Educational Module content reaches these objectives?	1	2	3	4	5							
9. Is the <i>written material</i> well organized?	1	2	3	4	5							
10. Are the <i>graphic illustrations</i> adequate to the Module objectives?	1	2	3	4	5							
11. Are the <i>simulations</i> appropriate for the Module objectives?	1	2	3	4	5							
12. Is there any conceptual error (misconception) in the Educational Module?	1	2	3	4	5							
13. What is your <i>final grade</i> to the Educational Module?	1	2	3	4	5							
Suggestions and Critics: For additional comments and critics, please write it down below.												

4.3. Sampling

Samples consisted of two distinct sampling groups, both constituted by students from this subject. In the semester 2003/2, it was offered to students of the Physics course that was divided in 6 peer. In the semester 2004/1 constituted a class with 4 peer of the Biological Sciences course.

5. RESULTS

As previously described, they developed a project along the course about specific topics in Physics and Biological Science. The projects are briefly presented in Figure 02 and 03.

6. DISCUSSION

Initially, Physics students had difficulties in working with STELLA. They faced difficulties in defining all variables to build a model about the topic under study. Moreover, they found it hard to translate the relevant variables to flow diagram variables, and in some cases sought the aid of mathematical equations to set possible relations, even without consistency among these variables. However it was possible to observe the students evolution concerning these aspects along the course and end up build quite consistent models.

The Biology students were capable of elaborating flow diagrams topology, but presented difficulties in attributing values to the relevant variables chosen. The strategy used was to stipulated values trying to generate graphic outcomes based only in tendencies, without considering the real numerical values promoting a semi-quantitative analysis for simulations outcomes[13].

Specific behaviours could be identified among the group: Physic groups in general, structured their modules in the theory about the theme studied and in the development of the model, the majority allowed users modification of variable starting values. Biology students presented more diversified works, bringing approaches closer to users quotidian. The modules produced were structured to integrate the theoretical content with modelling/simulation, aided by visual resources, although in excess sometimes.

Figure 02: Educational Module Developed by Physics Students

Theme	Module Structure			Final Evaluation		
	Module Description	Allow Change of Variables Value	Structured from the Articulation <i>Theorization/ Experimentation/ Modelling</i>	Average	Critics	Suggestions
Damped Harmonic Oscillator	<ul style="list-style-type: none"> It covered theoretical aspects; It explained the developed model and its results analysis. 	Yes	Yes	4.1	<ul style="list-style-type: none"> The non-familiar STELLA users would find difficulties; Lack of some physical concepts. 	Approach for the user to think about the concepts in her/his cotidian.
Circuits RC and RL	<ul style="list-style-type: none"> It started with a explanatory text about STELLA; It covered systems theoretical aspects with illustration and graphics; It allowed the four implemented models analysis. 	Yes	No	4.0	<ul style="list-style-type: none"> Navigation problems; Excess of buttons; Texts were hard to be understood. 	The project struture should start from the students quotidian.
RLC Circuit	<ul style="list-style-type: none"> It started with theoretical aspects describing and illustrating eache component of RLC circuit; It presented the model 	Yes	No	4.4	<ul style="list-style-type: none"> Illustrations and texts helped the user to understand the system 	The inclusion of topics related to the phenomena of resonance.
Plane Pendulum	<ul style="list-style-type: none"> It structure from the system modelling to represent the pendulum moves; It showed theoretical aspects of damped harmonic movement and some illustrations. 	No	No	3.9	<ul style="list-style-type: none"> The evaluation results indicated that the module objectives were partionally attained. 	Not only the interface but also the theory therein could be organized and explored to enable a better usage of it.
* First Law of Thermodynamic	<ul style="list-style-type: none"> It described the experimental procedure done with system modelling; It presented the First Law and related concepts, although lacking graphic resources to develop the topic; It explored the model. 	Yes	Yes	4.1	--	Insertion of illustrations and improvements in the graphics organization.
Universal Gravitation Law	When finishing the project, the student peer me a software problem, causing loss of files.					

* This project was presented in a Brazilian symposium in physics education[12].

Figure 03: Educational Module Developed by Biology Students

Theme	Module Structure			Final Evaluation		
	Module Description	Allow Change of Variables Value	Structured from the Articulation Theorization/ Experimentation / Modelling	Avarage	Critics	Suggestions
Home Water Consumption Study	<ul style="list-style-type: none"> It presented general data about the availability of potable water in Planet Earth; Led user to explore a series of suggestions about how to reduce the daily water waste to re-evaluate his habits. 	Yes	No	4.7	<ul style="list-style-type: none"> Objectives were clear and presented well-organized theoretical structure The navigation were considered excessively restricted 	--
Food Chain Study	<ul style="list-style-type: none"> It presented the Food Chain from the structuration of a model using STELLA storytelling tool. Simulation was observed in graphics, semi-quantitatively, the dynamic behaviour of the number of individuals forming the chain. It included examples of the chain in different habitats 	No	No	4.3	<ul style="list-style-type: none"> Theme comprehension was hard due to long texts and limited contents; Navigation buttons disposition was inadequate; Extreme use of visual resources. 	--
Chagas Heart Illness Study	<ul style="list-style-type: none"> It presented characteristic data covering the modes of contamination, prophylaxis, symptoms, parasites and Chagas illness vectors It brought an interactive model of the home and wild cycle of the parasite that causes the malady. It verified system dynamics with graphic results outputs of the simulation. 	Yes	No	4.3	<ul style="list-style-type: none"> Dialogue box to clear out the technical terms, as well as the structure with small texts makes user comprehension easy; Hyperlinks usage in the introductory text was considered to be difficult for the initial navigation. 	<ul style="list-style-type: none"> Improvement of design
Stoma Physiology Study	<ul style="list-style-type: none"> It presented general data about stoma with aspects interfering in its functioning. It structured from the guard cells volume variation model and consequently stoma open and close cycle. It allowed results semi-quantitative analyses with graphic outputs. 	No	No	4.3	<ul style="list-style-type: none"> Excessive use of buttons The hard finding of the hyperlinks in the text 	<ul style="list-style-type: none"> Improvement of design

7. CONCLUSION

The outcomes of this study lend support for improving the proposal for curricular innovation related to the subject *ISTSE* and for the research aiming at infusing ICT into the teaching-learning processes based on the modelling and computational modelling concepts.

Although Physics students used to reason with variables because of the nature of this subject area this study reveal, they tend to reason in terms of equations. This way, instead of trying to build their models starting from the causal diagrams among the relevant variables, they started establishing connections, even inconsistent, based on equation. Similar results were reported by previous studies[7][14]. In this sense, the proposal is to prepare adequate material that would lead the pupils to work with system thinking principles

Regarding the Biology students the difficulty was related to reason with variables in a quantitative way although they worked naturally in a semiquantitative way. It seems the reason for difficulty of finding numerical data that precisely translate biological phenomena. Therefore students used artificial numerical data to produce outcomes waited. This result leads to a twofold perspective: to choose adequate phenomena for the modelling to allow students to improve the quantitative reasoning and to include semiquantitative computer modelling environments to take advantage of their natural ability.

These preliminary results showed the use of the strategy based on the concepts of modeling and computer modeling seemed to be a good for the objectives of the subject. New studies are being carried out in order to implement the results report in this paper and to provide new directions for this perspective.

8. ACKNOWLEDGEMENT

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