THE USE OF SEMIQUANTITATIVE COMPUTATIONAL MODELLING IN THE STUDY OF PREDATOR-PRAY SYSTEM

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Abstract

The article presents results of the investigation on integration of computational modelling environment in the exploratory learning in topics of Science. The article presents results of the investigation about the integration of computational modelling environment to the exploratory learning of Sciences. The results here presented are relative to the study of the interaction and performance of students acting during the use of the computational modelling environment semiquantitative WLinkIt in an activity of specific content in Ecology: the predator-prey system. The results show that the students presented abilities to develop a model about proposed system and to relate and make comparison among the results of the model simulation with their previous expectation. In relation to the difficulties these were related to the delimitation of the system to be studied, in knowing where it is the value zero of the variable, to understand the function of a connection among two variables and in knowing as it is the influence of a variable on the other. Thus, this study presents important results for the continuation of research works about the use of computational modelling environment WLinkIt in the study of topics of Sciences.

Keywords: Exploratory learning, semiquantitative modelling, computational modelling, learning environment.

1 - Introduction

The use of new technologies in the educational context has been discussed worldwide. Recently in Brazil the federal government destined funds to public secondary schools for the acquisition of computers. However there is no clear policy or guidelines for the acquisition of softwares and Computational Modelling Environment.

This fact generates the need for the development of research aiming at promoting, in practice, the integration of the resources of the communication and information technology to the daily life in classroom (Ferracioli, 2000). In this context the objective of this research is to investigate the use of a Computational Modelling Environment in the study of topics in Sciences.

A Computational Modelling Environment is a software that in the context of this study is labelled in such way due to the existence of a underlying pedagogical proposal where they are seen as Learning Environment: in this perspective they are seen as tool for helping students to improve their ability of formulating question instead of simply find answers (Ferracioli, 2001).

2 - Theoretical Framework

The use of Computational Environment in classroom can be developed starting from the study of topics of specific contents in Science using an alternative approach through the **concept of modelling**.

This proposal consists of asking students to build a pencil-paper model about a specific topic in Science and afterwards to represent it in a Computational Environment. Once represented the model in the Computational Environment it can be simulated generating the possibility of deepening the study of this topic.

2.1 - About Modelling Activities

According to Bliss & Ogborn (1989) the activities of construction of models can be developed in two ways:

- **Exploratory**, when the student is asked to explore, in the computational environment, a model developed previously by a expertise;
- **Expressive**, when the student is requested to develop his/er own model in a computational environment.

In both perspectives the modelling activity naturally involves the process of reasoning and Bliss et al (1992) suggest that this process can be conceived in three dimensions:

- Quantitative
- Qualitative
- Semiquantitative

The quantitative reasoning involves a variety of aspects from the recognition of simple numeric relationships such as comparing sets of numbers as far as the manipulation of algebraic relationships. This reasoning dimension involves the understanding of how a change of a variable will affect others in a specific system such as in the case of the study of queues in a supermarket: how the increase of costumers will affect the waiting time in a queue.

The qualitative reasoning involves making categorical distinctions and taking decisions. This may consist of examining a set of choices and taking decision based on consideration of their consequences such as in the case of a journey when different means of transports can be chosen or considering a given goal that would be necessary to reach it. Therefore this perspective of reasoning demands the observation and consideration of alternatives and the careful analysis of evidences: **a student that wants to pass in the college entrance examination needs larger dedication to the studies.**

The semiquantitative reasoning involves the description of daily situations where the direction of a change in a part of a system is known but not the size of the effect of this change on the other parts. For instance, it is known that the increase of the intensity of light causes the decrease of the pupil aperture of the human eye (Sampaio, 1996): the analysis of this effect requests the understanding of the direction of the causal relationship - increase or decrease - but not the knowledge of the numeric values. In this work exploratory and expressive modelling activities demanded the use of semiquantitative reasoning.

The ground for analysing this dimension of the reasoning is based on the fact that as much the quantitative reasoning as the qualitative do not capture all the important aspects of the daily reasoning. Thus, the arguments used in the case of the pupil of the human eye includes a quantitative part and a qualitative part: the involved reasoning recognises the ordering of the amounts but not the magnitude through the use of the terms such as increase and decrease (Ogborn and Miller, 1994).

Therefore, the construction of models in a semiquantitative way can be based on a systemic thinking view (Forrester, 1968) that demands the understanding of the behaviour of a system based on the causal relationships among the variables that describe it. In this sense, causality plays fundamental role in the semiquantitative modelling because its underlying role in the reasoning for establishing the relationships among the variables.

2.2 - Causal Diagrams

The causal relationships among variables that describe a system can be understood and represented through a graphic representation of Cause-Effect Pair, labelled Causal Diagram (Roberts et al, 1983). Considering the example of the human eye behaviour a change in the light source intensity causes a change in the pupil aperture. This causal relationship is represented in the Figure 01 in a causal diagram format:

light source intensity ——(-)—— *pupil aperture*

Figure 01: *Example of a pair of Cause and Effect*.

The Causal Diagrams can be represented in the WlinkIt, a computational modelling environment based on an Iconic Metaphor.

2.3 – The Computational Modelling Environment Based on Iconic Metaphor, WLinkIt

WLinkit is an Computational Modelling Environment based on an Iconic Metaphor for the construction and simulation of dynamic models in a semiquantitative way. In this environment is possible to build models that represent causal relationships among important variables of phenomena, events, objects of the world to be modelling (Sampaio, 1996).

When opening the WLinkIt environment, the main screen is presented to the user as shown in Figure 02:

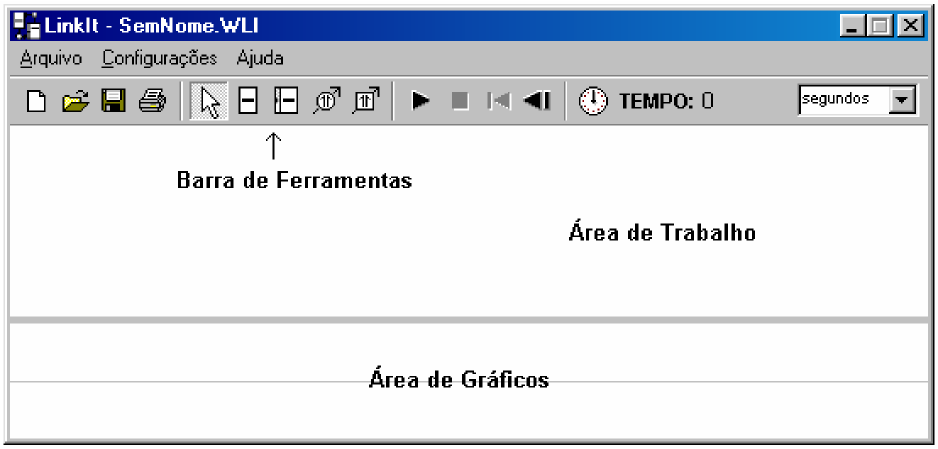


Figura 02: *The WlinkIt Main Screen*

The screen consists of 3 basic areas:

Work Area - this is the area for the construction of the model by the user;

Graphs Area - this is the area for the visualization of a graphic output;

Tool Bar - this is the area that contains the building blocks necessary for the construction of the model and tools for working with it.

The construction of models in this Environment demands a reasoning in a semiquantitative way. Thus, it is not necessary to know the mathematical relationships among the variables for the construction of a model because the WLinkIt building blocks establish the necessary calculations for the model to be simulated with the help of computationalprocedures avoiding the user cognitive load demanded by the programming and mathematical knowledge. In other words, it is possible the construction of a iconic model that will be translated in an adapted symbolic information from which calculations will be performed and inferences will be executed using those information whose results will be, for its time, translated again for the iconic form.

The model built through the Causal Diagram shown in Figure 01 can be represented in WLinkIt Environment as it is shown in Figure 03.

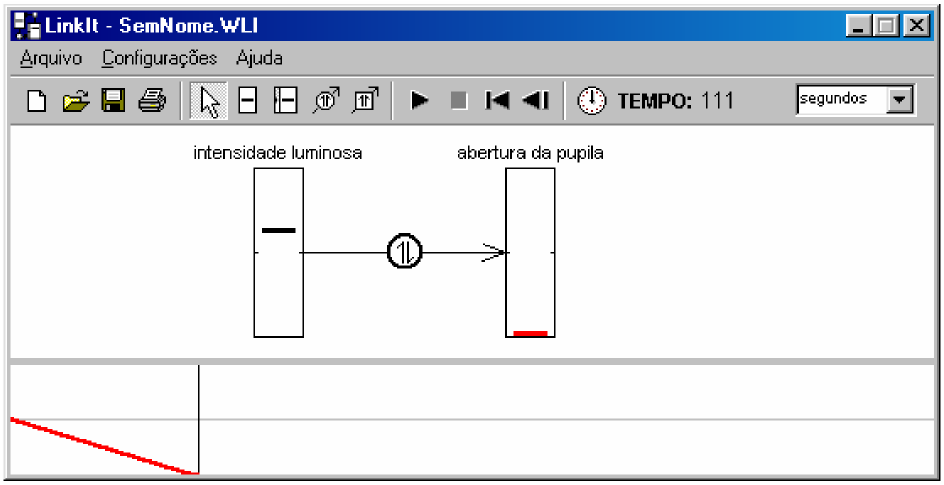


Figure 03: Representation of the Causal Diagram about the behaviour of the pupil of the human eye and the graph of the variable opening of the pupil

While the paper version of the model reveals its static nature, where an instantaneous view of the physical reality is privileged, its computational version is dynamic in the sense of the model can be simulated and the results help the process of restructuring and improvement of the initial model, facilitating, in that way, to visualise the temporary evolution of that same physical reality (Ferracioli, 1997a). During the simulation of a model the behaviour of each variable can be visualized through either its default bar level or the graph output that can be requested by the user.

2.4 - Strategy to Models Building

The process of building of a model and its representation in an Environment Computational Modelling is denominated Model Building Process. When building their own models students are requested to follow 7 basic steps:

- Definition of the *system to be studied*;
- Choice of the *phenomenon of interest* to be studied in the defined system;
- List of *important variables* for the building of the model;
- Building the model through Causal Diagrams;
- *Representation* of the model in the WLinkIt Environment;
- *Simulation* of the built model;
- *Validation* of the model from the analysis of its behaviour in relation to the waited behaviour of the phenomenon in study.

This procedure was proposed by Camiletti (2001) and represents global systematisation for the building model process beyond the consideration of the laundry list proposed by Mandinach (1989). The first two steps are based on fact that it should promote broadening of students view about the problem being studied.

This process can be developed to the study of the behaviour of the pupil exposed to a light source whose intensity can be varied. The steps are shown below:

- system to be studied is the pupil of the eye;
- *phenomenon of interest* is the behaviour of the pupil of the eye;
- the *important variables* are, at first, *light source intensity* and the *pupil aperture*;
- the construction of the model through a Causal Diagram is shown in the Figure 01;
- the *representation* of the model in Ambient WLinkIt and the result of the simulation, through graphic output, are shown in the Figure 02.
- The *validation* of the model is made by the user through the resources the animation of each variable and the graphic output. Thus, observing the graphic output of the variable *pupil aperture* it can be verified that it decreased when the *light source intensity* increased: this is in agreement with the observed phenomenon.

3 - Study Conception

SEMIQUANTITATIVE

In the last years it has been growing the number of studies about the integration of Computational Modelling Environment based on icon metaphor in the educational context. In the Physics teaching at university level it can be quoted Santos, Sampaio and Ferracioli, 2001; Camiletti & Ferracioli, 2001; Ferracioli and Sampaio, 2001 and in the teaching of topics of Science in general at basic and secondary level it can be quoted Bliss et al (1992), Santos and Ogborn (1992; 1994), Sampaio (1996), Sampaio and Towers (1999). These works report results that show that the use of the concept of modelling and the computational modelling based on the iconic metaphor in the educational context for the study of topics in Sciences is promising.

In this context, the present study was carried out to explore the possibilities of using the WLinkIt Environment for exploratory learning in Sciences at university level looking to two basic research questions:

1 - Which abilities the students showed during the development of the model?

2 - Which are the difficulties presented by the students during the development of the model?

3.1 - The Course

For the development of the research work it was structured a course *Modelling and Representation of Physical Systems with Computational Modelling Environment* ministered in 2 educational modules with duration of 2 hours each for university level students.

The two educational modules were organised according to:

- **Module 1 (02 hours) - Exploratory Activities**

  Introduction to the study of the System Thinking Reasoning and to the Computational Modelling Environment Semiquantitative WLinkIt.

- **Module 2 (02 hours) - Expressive Activities**

Modelling and Representing Systems with the Computational Modelling Environment WLinkIt.

The objective of the Module 1 was to introduce the students to the system thinking reasoning (Forrester, 1968) and to the Computational Modelling Environment WLinkIt through activities of exploratory modelling.

The objective of the Module 2 was to take the students to develop activities of expressive modelling with Environment WLinkIt on the Spring-Mass system and Predator-Prey system. The first activity to be developed was on the spring-mass system and soon after the activity was developed on the predator-prey system.

In this work only the result of the activities of expressive modelling with the Predator-Prey system are reported . For the development of this activity each couple was introduced to a text with basic information as described below:

> *An important characteristic found in the Nature is the one of the existent balance among the species. A typical example is it of the relationship between rabbits and foxes in a forest where human interference doesn't exist.*
>
> *It is known that in these local ones the rabbits, that feed of plants, are the main source of food of the foxes. Like this, when the foxes eat the rabbits, they can grow and to procreate. However, when the population of foxes begins to grow, more and more rabbits are necessary to feed them, what causes a decrease in the population of rabbits. Like this being, the population of foxes begins to be without food and consequently they decreases. With the decrease of the population of foxes, the remaining rabbits start to have more chances of to procreate and to increase its population.*

Soon after each couple was requested to build a model in the computer about this system and to discuss their ideas aloud.

3.2 Sampling

The participants in the course were university students from the second year of Sciences and Engineering courses at Federal University of Espírito Santo, Brazil. The students worked in peers and each couple attended the classes at a time. In the total, 6 couples developed the activities of the Modules 1 and 2.

3.2 - Data collection

All the activities developed by the students were video registered and the material writing was picked up.

3.3 - Data

The data considered for the analysis consisted of the material written by the students, of the versions of the model built by the couples and of the students' arguments.

4 - Data Analyses

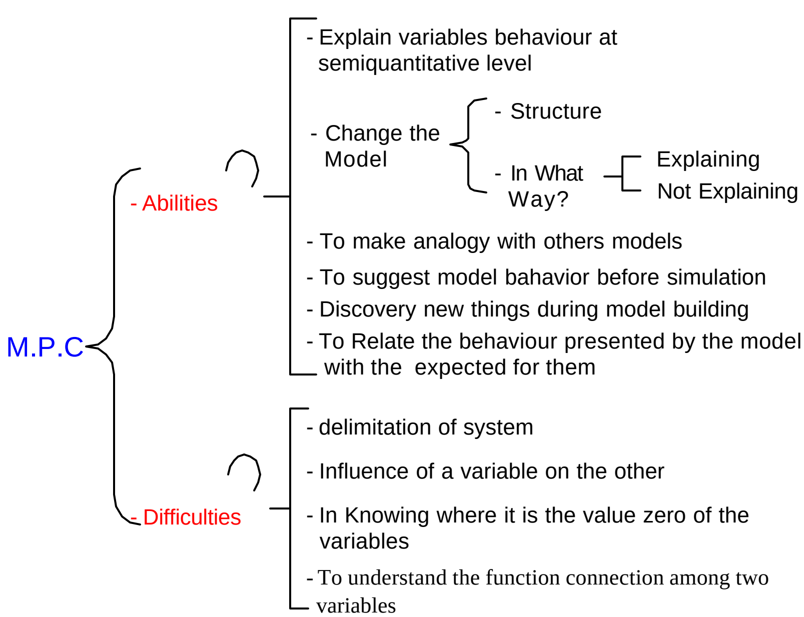
The data are of qualitative nature and the instrument used for the analysis of the data it went to Systemic Network (Bliss et al, 1983), due to possibility of structuring of categories in an including and complex way. In agreement with Ogborn (1994), a systemic network can be seen as an independent grammar of the context that defines a 'language' built to describe the data. The basic elements of a systemic network are:

- **Bracket** - used to represent group of exclusive choices
- **Key (clue) -** used to represent group of choices that happen simultaneously

The analysed aspect was the Model Construction Process, described in the section 2.4, and the systemic network built for the analysis of this Process. It is shown below in the Figure 04 and it is constituted of two basic aspects: **Abilities** and **Difficulties**. These aspects are represented in the first key, what means that are a group of choices that happen simultaneously, that is to say, the analysis of the Process of Construction of the model is made according to the ability aspects and difficulties. It is important to remind that from these more general aspects to the left and, proceeding for the right, the detailed level is going increasing to reach the more terms the right than they represent closer information of the gross data.

These two aspects are related to the basic subjects of research and they are constituted of categories, that can be seen in the left part of the Figure 04, that reflect the all the couples' characteristics. These characteristics were presented during the development of the activity of expressive modelling with the predator-prey system. In the right part of this Figure a summary in a table of the activities developed by the couples is also presented, where a reading in the column provides a visualisation of each couple's behaviour in the aspects of Abilities and Difficulties, while a reading in the line provides the visualisation of the all the couples' behaviour in that specific aspect.

Predator-Prey System



Couples						
01	02	03	04	05	07	Total
x	x	x	x	x	x	06
	x	x		x	x	04
	x	x			x	03
				x		01
x			x			02
		x				01
		x				01
x	x	x	x	x	x	06
		x				01
		x				01
	x			x		02
					x	01

Figure 04: *Systemic network and summary in a table to analyse data from expressive modelling activities with the predator-prey system.*

As example, the analysis of the Model Construction Process of the couple 01 is presented. In relation to the aspects of Abilities presented during the process of construction of the model the couple it was capable to relate the behaviour presented by the model with the expected for them. The first version of the model built for the system predator-prey was the Final Model too and the couple didn't present difficulties in this activity.

In relation to the couples' behaviour in each aspect considered in the systemic network, considering the Abilities presented by the couples, whole the students were capable to relate the behaviour presented by the model with the expected for them. In relation to the Difficulties, the couples 02 and 05 had difficulties in to know which position of the bar of level of Environment WLinkIt's variable represents the value zero of the variable.

5 - Discussion e Conclusion

The conclusion on the of Model Construction Process will be made answering the basic subjects of research of this work, described in the section 3, with base in the summary in a table.

5.1 - Which abilities the students showed during the development of the model?

The presented abilities varied of couple for couple. All the couples were capable to build a version of the model, to accomplish its simulation and to emit an opinion the behaviour presented by the model being said was or not in agreement with what they waited.

All the couples were capable to supply explanations at the semiquantitative level about the behaviour of the variables, that is to say, they were capable to explain what happens with a variable when the other varies. This result seems to indicate that the students were capable to ratiocinate at the semiquantitative level for the development of the expressive modelling activity.

All the couples were capable to change the model, inserting or removing variables and connections. Most was capable to explain these alterations done in the model that indicates that the couples presented a certain understanding degree on that they were doing, not adopting a strategy of simple attempt and mistake for the construction of the model.

Two couples were capable to do analogy with the model developed previously of the system spring-mass. This is an important ability in the measure that the student was capable to visualise a relationship among two models that represent systems of different nature. In agreement with Mandinach and Hugh (1994) these two couples obtained success in which they classify of transfer of abilities, once they were capable to use the abilities acquired in the construction of the model of a system, in this case spring-mass system, for the construction of a model of another system, in this case predator-prey system.

Forrester (1991) argues that the modelling can aid the student to organize, to understand and to structure its knowledge on the system in study. Thus, in this work it was observed that a couple seems to have understood some aspects of the system in study during the construction of the model of the predator-prey system, what seems to corroborate the author's argument.

5.2 - Which are the difficulties presented by the students during the development of the model?

For the development of the expressive modelling activities, the couples presented a series of difficulties, being some related to the use of Computational Modelling Environment WLinkIt, another related to the use of the reasoning in level of systems.

In relation to the use of Computational Modelling Environment WLinkIt, some couples presented difficulties in knowing the position that means the value zero in Environment WLinkIt's variable with the attribute 'Qualquer Valor'. Some couples conceived the value zero of the variable as being the inferior position of the same, what reflects the non understanding of the attributes of this variable type once the value zero of the variable is located in the central position of the same.

Still in relation to Environment WLinkIt's use, it was considered that the couple had difficulty in understanding the function of the connection among two variables, when establishing a connection among them they seemed not to understand the function of the same, that is to say, they seemed not to understand which would be the behaviour that would be generated by the built structure. Thus, it seems that the couple that presented this type of difficulty didn't possess a good understanding level about the function of the connection among two variables of the Computational Modelling Environment WLinkIt.

In relation to the use of the system thinking reasoning for the construction of the model, a couple found difficulties to understand as a variable influences the other, that is to say, it found difficulties in conceiving a variable as being responsible for the variation of the other variable.

Still considering the use of the system thinking reasoning, a couple found difficulties for the delimitation of the system to be studied. This ability is fundamental so that the student has clarity on which the aspects of relevance to consider in the construction of the model, otherwise some considered aspects and translated in the form of variables they cannot have importance for the model and the student can still imagine not a behaviour adapted for certain variable.

Thus, exists an indication that this difficulty is an inheritance of the traditional teaching, once, in general, it is not observed in an appropriate way the process of delimitation of the system in the moment of the study of a certain topic: it is assumed that the arrangement and manipulation of the system, with the establishment of the initial conditions are not belong the study once they are supplied a priori without an appropriate discussion. This fact is reaffirmed continually through the proposition of problems presented at the end of each chapter of Physics books: masses are compressed and placed in movement without they are mentioned the sources for the establishment of those concepts. (Ferracioli, 1994).

5.3 - Final Considerations

The objective of this research is to investigate the use of Computational Modelling Environment in the study of topics of Sciences. Thus, the mapping of the aspects here discussed it is fundamental to delineate of future researches in the sense of promoting, in the practice, the integration of these Environments in the class room, more specifically for the study of topics of Sciences.

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