

ADAPTING GOWIN'S V DIAGRAM TO COMPUTATIONAL MODELLING AND SIMULATION APPLIED TO PHYSICS EDUCATION

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Abstract

Several research papers in physics education suggest that computational activities in modelling and simulation are potentially useful to facilitate meaningful learning in physics, provided that students engage themselves in these activities and critically think about them. Sometimes, excited with the possibilities offered by technological resources, we imagine that some representations “speak by themselves” in such a way that students’ comprehension of physical phenomena will occur just by seeing them. However, to know how to use an instructional tool is at least as important as having it. In the case of computational modelling and simulation, for instance, it is not enough just to use them in instruction, it is necessary to make students think about what they are doing, about the physics involved in the models and simulations that they are dealing with. Thus, we decided to build an heuristic tool to help students in the task of creating and analyzing computational models useful to investigate the telling questions proposed regarding some physical phenomenon of interest. We created then what we call an **AVM** diagram which consists of an Adaptation of Gowin’s **V** diagram to computational **M**odelling and simulation.

AVM diagram

Among the many ways of using the computer in the teaching of science in general, and physics in particular, the computational activities of simulation and modelling stand out for potentially allowing students a better understanding of scientific models expliciting relationships among variables, the visualization of highly abstract elements, and their interaction with the content to be learned, among other things. These activities, as we see them, are distinguished from one another; basically, because of the access the student has to the mathematical or iconic model underlying its implementation. In a computational simulation representing a physics model, the student may add initial values to the variables, change parameters and, in a limited way, modify the relationships among the variables; however, he/she does not have autonomy to change the heart of the simulation (defined by a pre-established mathematical model), that is, to access the most basic constitutional elements. Student's interaction with the simulation has an eminently exploratory character. Computational modelling can also be thought in exploratory terms; in this case, the student receives a computational model ready and must explore it, but with the difference of having access to its basic features, even though, in some activities, he/she may not be asked to alter the basic structure of the model.

The exploratory activities, in general, are characterized by observation, analysis and interaction of the subject with previously built models so as to allow the perception and the understanding of possible existing relationships between mathematics, which underlies the model, and the physics phenomenon in question. In this kind of activity, the student is motivated to interact with the computational model, by answering questions presented as directed questions and "challenges". This interaction occurs through changes in the initial values and parameters of the model, using resources such as "scrolling bars" and "buttons" to facilitate the modifications. In the case of the exploratory activity of computational modelling, the student has access to the basic structure of the implemented model, being able to change it if he/she desires to do so.

Another possible way of working with computational modelling applied to teaching is the so-called expressive mode¹. The activities developed in this mode can be characterized by the developing process of the model from its mathematical structure to the analysis of the results it generates.² In this kind of activity, questions aimed at the elaboration of models from certain phenomena of interest, about which qualitative as well as quantitative information on the system may be given, are presented. The student can interact completely with his/her model, redesigning it as many times as it seems necessary to validate the computational model and the production of results that may seem satisfactory to him/her.

¹ Many times called "creation mode".

² In this category there are different forms of implementation of the computational model, for instance, inserting mathematical equations and/or building iconic diagrams in appropriate software, or using some programming language.

Based in the great success obtained through the usage of the V diagram, also known as Gowin's V (Gowin, 1981; Moreira & Buchweitz, 1993), in the analysis of the process of knowledge generation, and in order to extract knowledge documented in research papers, books, essays, etc., we decided to propose an **Adaptation of Gowin's V to Computational Modelling and Simulation** (the AVM diagram), as presented in Araujo (2005). The V form of the diagram, originally proposed by Gowin, is not something fundamental. Other forms could be chosen, but we adopted, for the AVM diagram, the V form because it shows the interaction between the two indispensable domains to the development of a computational model guided to the teaching-learning process of physics: the theoretical domain, related to the conception of the computational model; and the methodological domain, associated to the implementation and/or exploration of this model.

In the center of the AVM diagram, there is the phenomenon of interest, which we desire to approach and the focus-questions that direct the analysis/design of the computational model. In the basis of the diagram, there are the problem-situations, which are descriptions of the situation/event under investigation to answer the focus-questions that contextualize the phenomenon of interest.

The left and right side of the AVM diagram can be visualized in detail in figure 1. The left side of the diagram concentrates on the theoretical aspects of the planning/analysis of the computational model. This side shows the *philosophy*, that is, the systems of beliefs underlying the problem-situation modelling process; the *theories, principles, theorems and laws* that guide the development of the model; the *idealizations and approximations* assumed, which determine the context of validity of the model; the *internal entities* of the system being modeled and the external agents that act upon it; the signs by which they are represented; the *variables and parameters* used to represent states and properties of the entities of the model; the mathematical or propositional *relationships* (a technical statement such as "the bigger this.. the smaller that"); the *known results*, used for an initial validity of the model, which can be inferred from the theories, principles, theorems and laws assumed for the designing of the scientific model that we want to represent in the computer and which will also depend on the previous knowledge the designer has about the system represented. At last, we have the *predictions*, which are no less than initial attempts to answer the focus-questions before carrying out the model.

On the right side of the AVM diagram, corresponding to the methodological domain, there are: the *records*, that is, the data collected to try to answer the focus-questions; the *interactive elements*, related with the possibilities of altering parameters and variables during the execution time of the computational model; the *representations*, given by the model (graphics, table, etc.) and pertinent to the search for answers, obtained from the transformation of records; and the *modelling categorization*, according to the following classification concerning:

- a) mode (*expressive*: when a model is built by the subject; or *exploratory*: when the subject just explores it);
- b) kind (*qualitative*: linked to the modelling of linguistic constructions and textual productions; *semi-qualitative*: linked to the usage of causal diagrams, not involving numerical relationships; *quantitative*: bonded to mathematical models, involving numerical values and relationships as inequality and equations);
- c) implementation: in the expressive mode, a description of the way in which the model was implemented in the computer (through the use of metaphors, programming language, insertion of equations similar to manuscript form, etc.) and the tool used (*PowerSim, Fortran, Modellus*, etc.) In the exploratory mode, an indication of whether it is an autonomous simulation, or it needs to be executed in some program must be expressed. The computational tool used to build the simulation also must be indicated whenever possible.

Still on the right side of the V, we have the *validation of the model* step, in which we compare the known results with the ones generated by the model. In case there is a disagreement between them, the model is considered unsatisfactory and must be modified until it comes to reproduce the known results. In this stage, the model is said to be validated. Then, we come to obtain the model assertions, that is, the answer (s) to the focus-question(s) that are reasonable interpretations of the records and representations supplied by the model, also allowing the evaluation of the predictions. At last, we have the *possible generalizations and expansions* of the model, which are the generalizations about the applicability of the structure of the model and how to expand it in a way to include variables and relationships not considered initially (change in idealizations and principles), broadening its context of validity.

It is important to emphasize that there is a permanent interaction between both sides of the AVM diagram in a way that everything that is done in the methodological side is guided by the components of the conceptual side in an attempt to develop/analyze the model and answer the focus-questions. This interaction mimetizes the recursivity intrinsic to the modelling process. We propose four applications of the AVM diagram to the teaching of computational modelling and to the exploration of computational simulations to the learning of specific contents.

- 1) Guided exploratory mode: in the AVM diagram, the phenomenon of interest, the focus-questions and the problem-situation are defined by the teacher and a computational simulation is presented. The reflexive elaboration of the V will serve as a guide to the exploration of the model so as to answer the focus-questions. Activities built this way may avoid that students distract themselves with details and end up not capturing essential aspects of the model focused by the teacher, especially when in too elaborate and "realistic" simulations.
- 2) Open exploratory mode: a computational simulation is presented and it is asked that, through the AVM diagram, the student explores the model in a reflexive manner, paying special attention to the formulation of the focus-questions. This mode may be especially useful for designing educational materials from the simulations created by others, which is interesting to the teacher, who can come to use the materials available in the web, for example, as well as to the students.
- 3) Expressive guided mode: in this case, the phenomenon of interest, the focus-questions and the problem-situation are previously supplied by the teacher, while the student elaborates the rest of the V and designs the corresponding computational model. This mode can be used when we desire the students to build a computational model about a specific content, taking in consideration focus-aspects defined by the teacher.
- 4) Open expressive mode: these are proposed activities in which the student must design a computational model from the reflexive elaboration of the AVM diagram, defining him/herself the focus-questions and the problem-situations which will guide his/her work. This way of using the AVM diagram may also guide the teacher in the building of his own models.

During the process of creation of the AVM diagram as an heuristic tool for the computational modelling and simulation applied to the teaching of physics, we considered the five non-hierarchical stages defined by Halloun (Halloun, 1996), the six stages defined by Santos & Ogborn (1992), the strategy for building models presented by Ferracioli & Camiletti (2002), the considerations on the modes and kinds of computational modelling activities done by Santos & Ogborn (1994) and also elements of the P.O.E. (Predict Observe Explain) methodology (Tao & Gunstone, 1999). These elements appear "diluted" in many fields of the AVM diagram and their stages, in the dialectic process of its development.

In the teaching activities of the exploratory mode, we motivate the student to question him/herself about the existing relationships among the many variables involved, driving him/her to constantly question about the effects of his/her actions upon the results generated by the model. This questioning can usually be described as: If I alter "this" what happens to "that"? This causal underlying reasoning acts as background to the promotion of interactivity. In the expressive mode teaching activities, the AVM diagram was conceived to serve as an heuristic tool to the development of computational models applied to teaching.

Example

In figure 2, an example of AVM diagram is given. It is just an example, not an exemplar. It was made by an introductory college physics student, in the expressive guided mode, has inadequacies in the scope of physics, for example, the assumption that the electric current in the circuit increases during the charging process of the capacitor. This AVM diagram was chosen as example because it illustrates well the difference between known results (which we assume as true in the designing/analysis of the computational model), and the predictions (answer attempts to the focus-questions). In an AVM diagram developed by someone who knows the content, and, therefore, who previously knows the answers to the focus-questions, the results obtained and the predictions may superimpose each other.

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Figure 1 - Adaptation of the epistemological V to computational Modelling

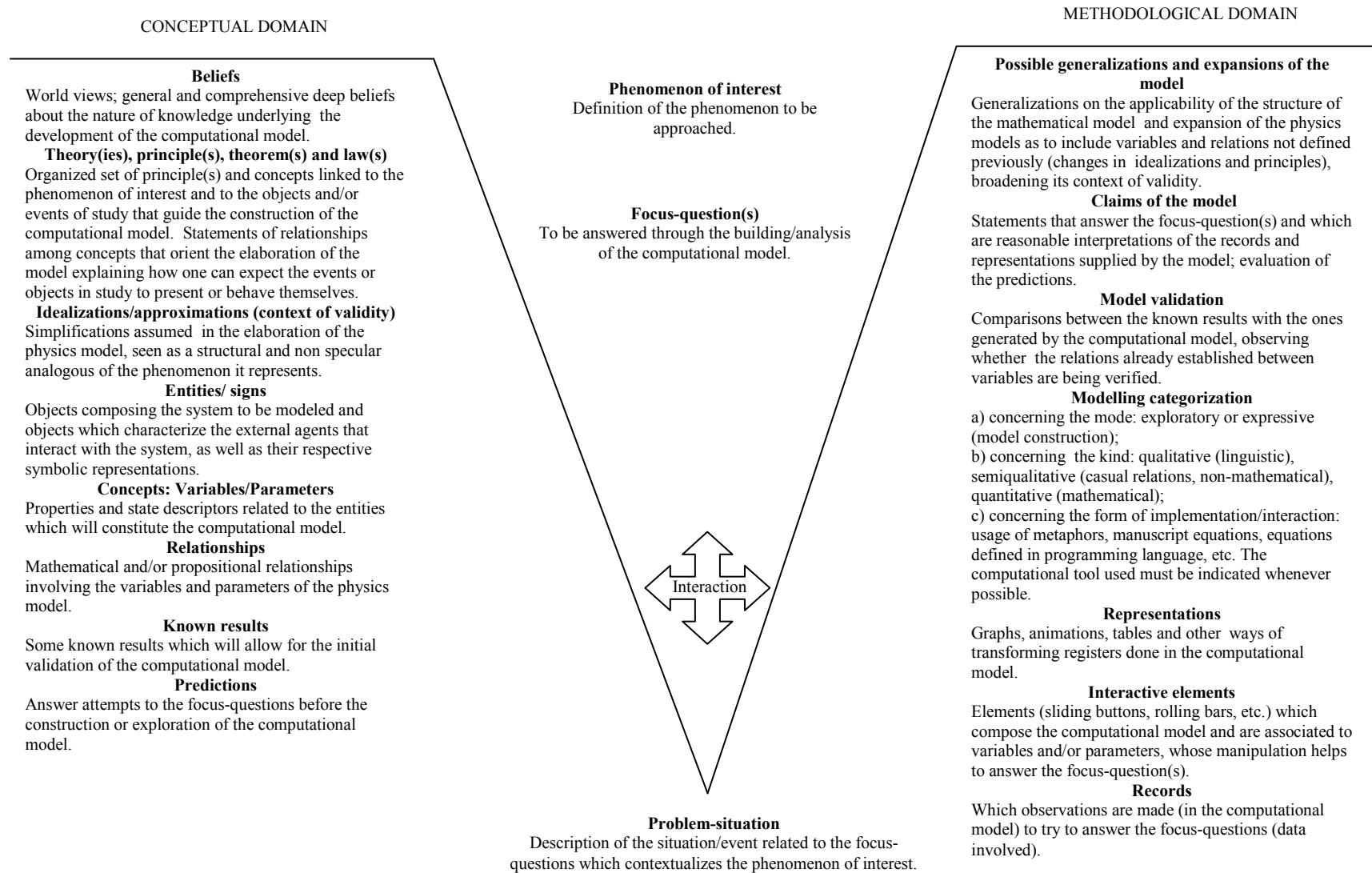


Figure 2 - AVM diagram for building a RC circuit model from the point of view of a beginner student (notice the errors in the predictions)

