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The computational experiment and its effects on approach to learning and beliefs on physics

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A R T I C L E I N F O

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A B S T R A C T

Contemporary instructional approaches expect students to be active producers of knowledge. This leads to the need for creation of instructional tools and tasks that can offer students opportunities for active learning. This study examines the effect of a computational experiment as an instructional tool-for Grade 12 students, using a computer simulation environment created in Java for the domain of "linear oscillations without damping".

In this study we use the computational experiment as an integration of the computational science with the discovery learning method. The computational experiment supports both types of research, the exploratory as well as the inventive research, helping the learners to develop not only exploratory but also expressive models.

The aim of the paper is threefold. At first we want to examine the influence of the computational experiment on students' learning performance. The other two aims are related to the investigation of the experiment's influence on students' approach to learning and their beliefs on physics. Our results indicate that there is a strong shift on students' conceptual understanding and to the consideration of the coherence of physics, as well as to the realization that physics is strongly connected to mathematics. Finally students realized that mathematics, physics and information theory are strongly connected cognitive disciplines.

1. Introduction. Computational Physics-modelling and simulation

Simulation-based learning involves learning performed in a computerized environment, in which the learner interacts with the entities of the environment and gradually infers the features of the concept model whilst he/she proceeds through the simulation, which may lead to changes in his/her original concept (de Jong & van Joolingen, 1998).

Studies on how computerized environments improves learning performance have produced diverse results, with some of them finding that simulation-based learning does not significantly improve the test results of learners (Reamon & Sheppard, 1997). Other researchers stated that there was no significant difference between simulation-based learning and narration-based teaching (Carlsen & Andre, 1992), whereas others stated that there are significant advantages of simulation-based learning (Chang, Chen, Lin, & Sung, 2008; Colaso et al., 2002; Luo, Stravers, & Duffin, 2005; Naps et al., 2003).

According to Scardamalia and Bereiter (1991); Fund (2007), computer learning environments, if appropriately designed, can support constructivist and exploratory learning, giving learners more agency in the learning process. Consequently, the whole discussion leads to the fundamental question: under what conditions can simulation-based experiments enhance learning results and what kind of simulation is appropriate for learning?

Redish and Wilson (1993) proposed an approach in physics teaching where students should be engaged in problem solving using programming languages. They considered that creation of programming could lead to more advanced code and thus to self-explained programming code, as well as to the algorithmic approach. Directly connected to that approach, is that proposed by Sloot (1994) as Computational Physics (CP). One of the crucial components of this research field is the correct abstraction of a physical phenomenon to a conceptual model and its translation into a computational model that can be validated. This leads us to the notion of a *computer experiment*

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where the model and the computer take the place of the 'classical' experimental set-up, and where simulation replaces the experiment as such. The stages of the computational experiment are presented in Fig. 1.

According to Landau, Pαez, and Bordeianu (2008), CP provides a broader, more balanced, and more flexible education than a traditional physics major. Moreover, presenting physics within a scientific problem solving paradigm is a more effective and efficient way to teach physics than the traditional approach. Landau et al. (2008) suggest that CP education presents the path forward, because it integrates the tools and results from research into education and because of using research-rich experiences to stimulate and activate students.

The same authors call CP "physics education *with* research" instead of "physics education research", which seemingly focuses on students' ability and failure to learn various physics concepts. According to them, CP is a multidisciplinary subject combining aspects of physics, applied mathematics, and computer science (CS) with the aim of solving real problems incorporating a methodology. The methodology of CP is depicted in Fig. 2.

Tobochnik and Gould (2008) argue CP should be incorporated into the curriculum because it can elucidate the physics. Computation is both a language and a tool and in analogy to models expressed in mathematical statements, in CP models are expressed as algorithms, which in many cases are explicit implementations of mathematics.

Computational Physics and Science Education are closely related to the concept of modelling and simulation and it is quite reasonable to attempt to describe the process of teaching in terms of a model and simulation because it is known that models can lead to improvement in our understanding of natural phenomena (Glazek, 2008).

Modelling and Simulation receive increasing attention from the science education community as important components of a contemporary science education (Gilbert, 2004; Gilbert, Boulter, & Elmer, 2000; Greca & Moreira, 2002), both because they reflect the nature of science, and because modelling and simulation activities are considered useful for learning concepts and processes.

According to Recchi, Gagliardi, Grimellini, and Levrini (2006), effective computer simulations are built upon "mathematical models" in order to accurately depict the phenomena or process to be studied, and a well-designed computer simulation can engage the learner in interaction by helping the learner to predict the course and results of certain actions, understand why observed events occur, explore the effects of modifying preliminary conclusions, evaluate ideas, gain insight, and stimulate critical thinking.

Chonacky (2006) stated that Computational modelling and simulation are two of the most successful methodologies that have been applied to sciences and engineering research. He also emphasized, in the Introduction to the GIREP-2006 symposium on Computational Modelling Issues for Physics Courses, that education is one of the venues of Computing in Science and Engineering (CiSE). Modelling can be considered as a pedagogical tool that involves cycles of model construction, exploration of model characteristics, application of model to a specific problem, evaluation and revision, while it resembles authentic activities of scientists (Gilbert et al., 2000). According to Jonassen (2000) the most effective way to support the construction of mental/conceptual models is to engage learners in using a variety of tools for constructing physical, visual, logical models of the phenomena.

1.1. Modelling indicators and research spaces in discovery learning

It is known that any simulation technique, corresponding to a model, has 3 indicators, namely (Garzia & Garzia, 1990):

Validation: it refers to the building of the right model so that the conceptual model can be considered to be accurately representing the real system. The validation is done by comparing the model to what is generally accepted as the real system.

Verification: it refers to the certainty that the computer simulation acts, as it is intended to, against the conceptual model that has been designed. This generally involves debugging the code and can be aided by using modules of code. It also includes testing the system under a number of input parameters. The final step (*Credibility*) of the simulation is to ensure that the models are *credible* which is to see if the simulation is accepted as being accurate and can be extended to other applications.

The above mentioned indicators should be taken into account when we deal with the ICT and discovery learning using ICT in Education. Despite the fact that in literature there are different classification schemes for discovery learning (Friedler, Nachmias, & Linn, 1990; Kuhn,

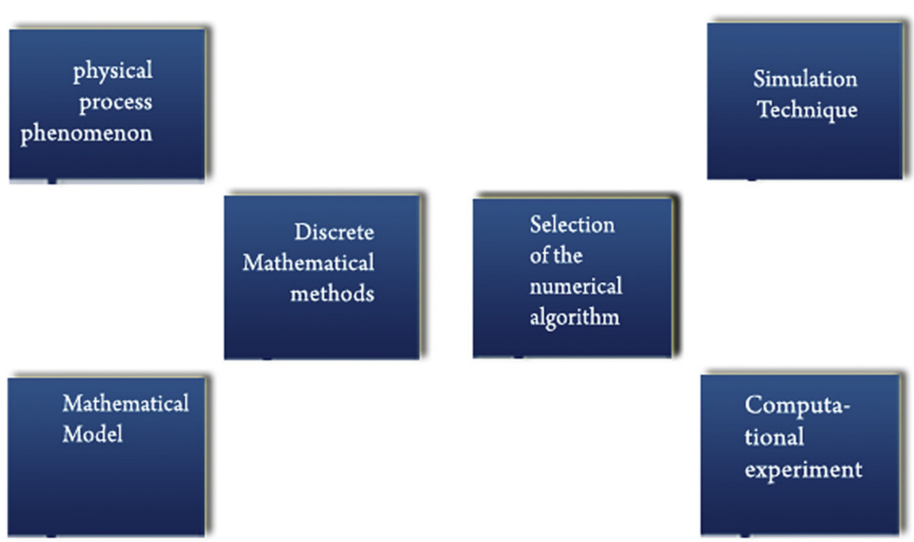

Fig. 1. The functional stages of the computational model and experiment (Sloot, 1994).