TEACHING PHYSICS WITH MODELLUS - A CONSTRUCTIVIST APPROACH: FROM COGNITIVE CONFLICT TO CONCEPTUAL CHANGE

ALEXANDER PATRIKIOS, ATHANASIA RAPTIS

Pedagogical Department of Primary Education , National & Kapodistrian University of Athens, 20 Ippokratous st. Athens, Greece, 106 80
Tel: (+30) 210 7519796, alpatrrk@primedu.uoa.gr, athana@primedu.uoa.gr

Abstract

One of the most important issues in physics instruction is that students, in their effort to explain physical phenomena, use their experience to form their mental representations. These representations are usually incompatible with the current scientific knowledge. Students understand the deficiency of their previous ideas and reconstruct new ones; compatible with scientific "reality", through the cognitive conflict — conceptual change process. In this study we use the Modellus software in order to examine the effectiveness of an alternative computer — based teaching methodology in the achievement of the above process. The results of the study show that teaching physics with the aid of simulations makes it easy for students to comprehend their misconception and construct new knowledge.

INTRODUCTION

A fundamental assumption of the constructivist approach to learning is that knowledge is not transmitted from the teacher to the student but it is rather constructed in the student's mind during his active engagement in the whole learning process in some meaningful way based on experience. This construction has a subjective character as it is based on students' prior mental schemas. Furthermore, the construction of knowledge is socially determined and understanding is mediated by the cultural agents, tools, signs and interactions with our social environement (Vygotsky, 1978). Thus, it should be realized in a meaningful social context. The work in groups and the afterwards discussion sets up the conditions for the social facilitation of knowledge construction.

From Cognitive Conflict to Conceptual Change

A great deal of educational research in the field of physics teaching has shown that students trying to explain various physical phenomena, form, through their experience and their social interaction, mental representations, which are usually incompatible with the current scientific knowledge (Driver et al. 1985). It is referred to as misconceptions and they have a great explanatory ability for students (Duit, 1995). They are integrated mental schemas with internal consistency which represent the real word. (Vosniadou, 1994 Driver, 1995, Raptis & Raptis, 2006:93)

As relative studies have also shown, the traditional way of physics instruction is ineffective in aiming students to overcome their misconceptions (Dykstra et al. 1992). It must be noted that students are often reluctant in abandoning their prior ideas and adopting new ones more consistent to the scientific truth (Driver et. al., 1994).

Among the basic misconceptions in Physics related to the 1st and 2nd Newton's laws, are the following (Driver et. al., 1994):

- If there is motion, there is a force that acts (1), and
- The heavy objects fall faster than the light ones, due to the fact that gravity causes to the former a higher acceleration (2).

One of the most characteristic ways to construct new and scientifically «correct» knowledge is the process in which students understanding their wrong ideas recreate new ones. It is the process which, under certain facilitative conditions, begins from the cognitive conflict and concludes to the conceptual change. By applying the appropriate teaching strategy, students think about their prior and wrong ideas so as to understand whether or not they (the ideas) are functional and applicable. In case they find out that their ideas are inadequate in explaining some phenomena in a consistent way, the cognitive conflict appears as a precursor to the conceptual change. In order to achieve the cognitive conflict, the following conditions must be valid (Posner et al. 1982):

- Students should be discontented with the existent (mis)conception.
- A new meaningful conception should be appeared. (In a facilitative and appropriately designed learning context)
- The new conception should be plausible and solve some the problems that the old one cannot.
- The new conception should open up new areas of search and inquiry. (Pupils are now able to deal with more advanced ideas and generate new questions)

Difficulties in Achieving Cognitive Conflict

The cognitive conflict cannot be always achieved easily nor has it the desirable results. Among the difficulties that potentially appear during the learning process can be (Duit, 1995):

- Students' reluctance to be engaged in a process of comparing their ideas with the dominant scientific aspects (they usually pursue to obtain the correct answer from the beginning.
- The complexity of the physical phenomena which makes them insensible and so they have a rather abstract and symbolic character.
- The fact that while the incompatibility of students' ideas is obvious to the teacher; this is not the case for the children.

Teaching strategies which lead to the cognitive conflict and then to the conceptual change can be the maieutic (socratic dialogues), analogies, metaphors, laboratory activities with the aid of computers and especially the modelling and simulation software (Vosniadou & Brewer 1987; Posner et al. 1982). In this study we use Modellus in a physics course in order to examine the effectiveness of the specific software, (under the condition that it is used in a pedagogically sound learning environment) in promoting conceptual change and consequently in students' understanding of their misconceptions. We also examine the extent to which this particular learning environment promotes social learning (Vygotsky, 1978) through students' interaction and helps them students in building up new knowledge, as well.

MODELLUS DESCRIPTION

Modellus is a two–dimensional open computer environment, appropriate for designing and creating physical models. With the aid of the software one can design and build models for several scientific fields (e.g. Mathematics, Physics, Chemistry, Economy, e.t.c.). Students are able to experiment with the simulation by changing the values of the parameters (before or during the run–time) and observe the effects of their changes. They are thus guided to deductions which are very close to scientific knowledge. Modellus' basic features are:

- Multiple representation of a phenomenon (e.g. using Animation, Graphs, Equations, Value Tables)
- High Interactivity as well as dynamic, revising possibility
- Ability to embed graphs, picture files (bmp and gif format) and video files.

OBJECTIVES

The main learning outcomes of our instructional design are:

- Students should be able to overcome their basic misconceptions regarding the 1st and the 2nd law of Newtonian Mechanics.
- They should be able to understand new physics concepts and to construct new knowledge.
- They are expected to be able to apply this knowledge in order to develop effective problem solving strategies and solve complex physics problems.

INSTRUCTIONAL APPROACH - METHODOLOGY OF THE STUDY

This instructional design with the use of Modellus has been applied to a group of students attending the first grade of Lyceum (3) in the context of a constructivist, authentic, student-centered, explorative, experiential and collaborative learning environment (Wilson, 1996) .

In order to examine the learning outcomes as well as some aspects of the learning process during the application of our instructional design with the use of Modellus, a qualitative educational research has been made by the authors. A questionnaire referring to the student's personal data, a pretest and a post-test of the students' achievement and thinking modes, the students' actual responses to the sheets used, as well as their recorded dialogues during their collaborative work have been the fields of our study as well as the tools for collecting our research data. Content analysis technique as well as some statistical basics have been used in order to analyze data and develop some understanding of the process of the students' conceptual change, problem solving approaches and evaluation of the whole experience.

PROCEDURE

Students had been already taught the relative physics topics in their school. Before the instruction, students were given a pre–test so as we could find out their misconceptions and their prior knowledge in physics. The course (eight models created and equal in number activity sheets designed) began with a short examination of the 1st and 2nd degree polynomial functions and continued with the examination of the linear motion with constant velocity, the linear motion with constant acceleration, the free fall, the horizontal projectile motion and the projectile motion at an angle (4). In each case the students were asked to change parameters in a specific way, to run the simulation, to observe the results and then to complete the activities in the correspondent sheet (See As Examples Figures 1 and 2). In some cases data are exported from Modellus and imported to Excel for further processing.

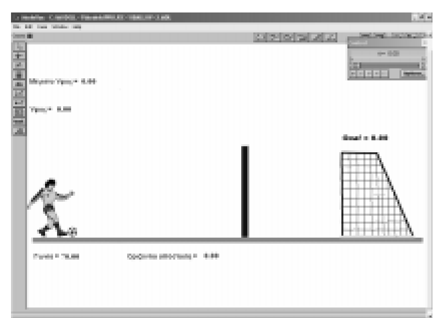

Figure 1: Find the angles at which the football player scores

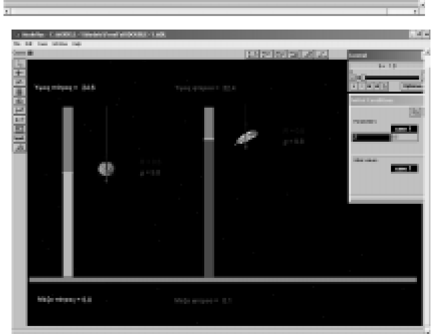

Figure 2: Find which of the two objects will reach Earth first.

After the instruction, students were given a post–test so as we could find out whether or not the whole application contributed to the achievement of the initially posed objectives.

RESULTS

The results of the study showed, among others, that:

- Students, to a great extent, reconstructed their mental representations regarding the 1st and the 2nd law of Newtonian Mechanics successfully.
- They obtained, in a rather easy and agreeable way, new knowledge (projectile motion at an angle)
- Their critical ability in solving physics problems and exercises (in the post test) was remarkably improved.
- The specific modelling tool, together with the teachers' supportive mediation as well as the student's task-oriented collaborative interaction, proved to be significant facilitative factors for the students' learning and positive attitude development towards Science school work.

CONCLUSIONS

The findings of this study show that teaching with the aid of the specific software, as well as with any similar tools (Komis, 2004), helps students to understand their misconceptions, to reconstruct their mental structures regarding physics concepts and to apply them in solving exercises, more easily than in the traditional physics teaching. In the context of the application, some new misconceptions were detected. These misconceptions are documented in the international bibliography of physics instruction. Finishing this study, it must be noted that computers made the whole learning process very attractive to students, even to those who have almost no experience in using one, due to the specific tools' modeling qualities and to some tacit and social learning effects that took place in front of the computer during the students' collaborative work.

Notes

(1) This misconception is related to the linear motion with a constant velocity or a constant acceleration.

(2) This misconception is related to the gravity and the free fall of an object

(3) Lyceum is the upper secondary education Greek school containing three grades.

BIBLIOGRAPHY

Driver, R. (1995). Constructivist Approaches to Science Teaching. In Steffe L., Gale J. (ed), *Constructivism in Education,* Lawrence Erlbaum Associates, Publishers.

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense of secondary science: Research into children's ideas*. New York: Routledge.

Driver, R., Guesne, E., & Tiberghien A. (1985). *Children's ideas in science*, 385. Open University Press, Milton Keynes, UK.

Duit, R. (1995). The Constructivist View: A Fashionable and Fruitful Paradigm for *Science Education Research and Practice, 275*. In Steffe L., Gale J.(ed), Constructivism in Education, Lawrence Erlbaum Associates, Publishers.

Dykstra, D. I., Jr., Boyle, C. F., & Monarch, I. A. (1992). Studying conceptual change in learning physics. *Science Education*, 7I (6), 615-652.

Posner, G. J., Strike, K. A. Hewson, P. W. & Gertzog, W. A. (1982). Accomodation of a scientific conception: Toward a theory of conceptual change. Science Education, 66, 211-227.

Komis, V. et al (2004). Teaching Science with the Use of a Modeling Educational Software, In: Kekes, *ICT in Education. Designing and Application Issues: Philosophical and Social Perspectives. Athens: Atrapos,* 105-128. (In greek)

Raptis, A. & Raptis, A. (eds) (2006). *Learning and Teaching in the Information Era — A holistic approach*, V.1, Athens (In greek).

Vosniadou, S. (1994). Conceptual Change in Childhood. In Vosniadou, S. *Texts on Developmental Psychology*, V. 2: Thought, Gutenberg, Athens (In greek).

Vosniadou, S., & W. F. Brewer, (1987). Theories of knowledge restructuring in development. Review of Educational Research, *57, 51–67.*

Vygotsky, L. S. (1978) Mind and Society. Cambridge: Harvard University Press

Wilson, B.G. (1996). *Designing constructivist learning environments.* Englewood Cliffs, N J: Educational Technology Publications