The Computer as a Key Component in the Conceptual Learning of Physics

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Abstract

The rapid progress of modern society and the rapid changes in the world demand that students should, during the educational process, develop skills such as creativity, initiative, a readiness to solve problems and, most of all, a readiness to adapt to the continuous changes in the world. In traditional ex-cathedra teaching, students usually do not develop such qualities, therefore over the last two decades, researchers have been searching for new, innovative approaches in teaching and learning all over the world. A lot of them have been exploring the effectiveness of Information and Communication Technology (ICT), primarily of the computer, as an important tool for the improvement of the educational process. Project COLOS (Conceptual Learning of Science) encourages the use of ICT for teaching and learning and the conceptual learning of Physics is, with the rapid progress in computer technology, a very promising teaching approach. Our research confirms the great potential of utilising computers in Physics lessons. In the experimental investigation we compared the conceptual way of learning Physics with the traditional instruction of Physics. The main goal of our study was to confirm the successfulness of the conceptual approach with emphasis on the usage of the computer and, with the results of our research, to highlight the necessity of including ICT in the modern educational process.

1. Introduction

In the last decade there have been many researchers who have, in their studies, warned that computer assisted or ICT assisted teaching should provide educational support wherever its use is feasible or reasonable. Chang and his co-workers have, in their article, made an overview about previous researches, which have confirmed the effectiveness of instruction supported by computer simulations [2]. They have also, in their own research, confirmed the successfulness of this teaching approach with emphasis on the usage of computer simulations. Wieman and his co-workers have explored the effectiveness of selected computer simulations in lessons [6]. They have emphasized that interactive simulations are new and very powerful tools in the educational process.

Recently in the world and in Slovenia, we have been promoting the conceptual learning approach in Natural and Technical Sciences through the so-called COLOS (Conceptual Learning of Science) project [5]. The COLOS project was founded in 1988 and because of the rapid development of computer technology in the last decade, conceptual learning and teaching is becoming a very promising teaching method, particularly in the domain of Physics. The primary goal of conceptual teaching and learning is learning from experience. The emphasis in the conceptual approach is that students should first become familiar with the effects of natural or technical law and only then do they receive its theoretical and mathematical background, so conceptual learning enables a better understanding of the abstract mathematical models and real world events. The correlation between real life phenomena and abstract mathematical models is very important in the learning of Physics. In traditional approaches there is a big emphasis on "tasks solving with appropriate equations" and students often actually do not understand the basic concepts of selected phenomena or problems.

2. The conceptual approach in teaching Physics

Unmotivated learning using a template of pattern solving principles and with minimal creativity has no future in the modern educational process. There is evidence which shows that computers or ICT open new types of pedagogical activities and encourage the curiosity and creativity of students [4]. So ICT, in particular the computer, could be a solution for the improvement of teaching approaches because it offers the opportunity to incorporate motivational and research-based problem solving approaches into Education. The

computer is one of three basic components in the conceptual teaching and learning approach. The components are: ICT, notably the computer, experiments and problem solving.

The conceptual way of learning and teaching Physics is problem based and for such an approach we exploit the potential of models, animations and simulations [4]. With the use of computer simulations students have the opportunity to solve much more complex problems than when using traditional approaches.

In the beginning simulations required expensive graphics workstations but, with the development of the World Wide Web and advances in computer technology, they are now available for all levels of education. Over the last decade we have started using Java programs – applets, which in combination with hypertext present a modern form of the interactive textbook [4]. There is also another technology – JavaScript that introduces the client process and turns static web pages into dynamic ones; so JavaScript also enables web interactivity. The cooperation of hypertext and dynamic elements led to the development of applets. Applets (Figure 1) are controlled by the scripts and can co-exist with the hypertext.

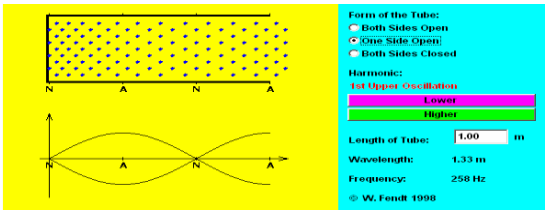

Figure 1: Example of physical applet.

When an applet is designed for the small domain of Physics, we talk about physlets. Prof. Wolfgang Christian from Davidson College, North Carolina, introduces the concept of physlets [3]. Physlets (Figure 2) are Java applets, developed for the teaching of Physics, and can be controlled with JavaScript.

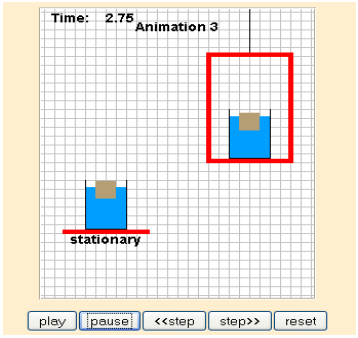

Figure 2: Physlets for exploration of accelerated movement.

Physlets - "physical applets" are small, adaptable Java applets, which are usable as simulation models in web applications. The many attributes of physlets gives them special educational value. They are simple, use uncomplicated graphics and each physlet is focused on one Physics phenomenon. Physlets are small in size, so they can be easily downloaded from the web. They do not have unnecessary details, which can be more misleading then helpful. Physlets can be used as construction elements in almost every teaching plan and in almost any teaching approach, but they play a crucial role in the conceptual approach in learning and teaching Physics.

The conceptual approach exploits the great potential of computer technology and we were interested in how big an improvement could be reached in the teaching goals.

3. Experimental study

We conducted an experimental study in which we compared the conceptual approach, with emphasis on the usage of computers, and the existent traditional approach. We were especially interested in the effectiveness of the conceptual approach in the higher thinking skills such as Analysis, Comparison, Inference and Evaluation.

The main goal of our study was to research the successfulness of the conceptual way of learning, with the computer as a key component of this approach, when teaching topics in the domains of Electricity and Magnetism to the third year class of Slovenian 4-year high schools. We tested five thinking processes (knowledge, analysis, inference, comparison and evaluation). 80 third year students from school took part in the research, 40 of them were taught physics traditionally (control group) and 40 in a conceptual way (experimental group). Two teachers were teaching them in the school year 2009/10, for a total of six weeks - three weeks on topics about Electricity and three weeks on topics about Magnetism. Students took a written pre-test before carrying out lessons in both domains. After learning about Electricity they had a post-test and also after carrying out lessons on Magnetism. In the traditional approach we used standard didactical materials – textbooks and a collection of exercises. On the other hand, for the conceptual learning and teaching method, we prepared interactive worksheets for use with the computer. Students worked in pairs on computers (Figure 3), and they researched, without the standard teacher`s explanation, selected phenomena of a specific topic. Due to the enthusiasm of the students, the classes were slightly noisier.

Figure 3: Students working with computers.

3.1 Results of pre-tests

First of all we will present the results of the pre-tests in the domain of Electricity (Figure 4).

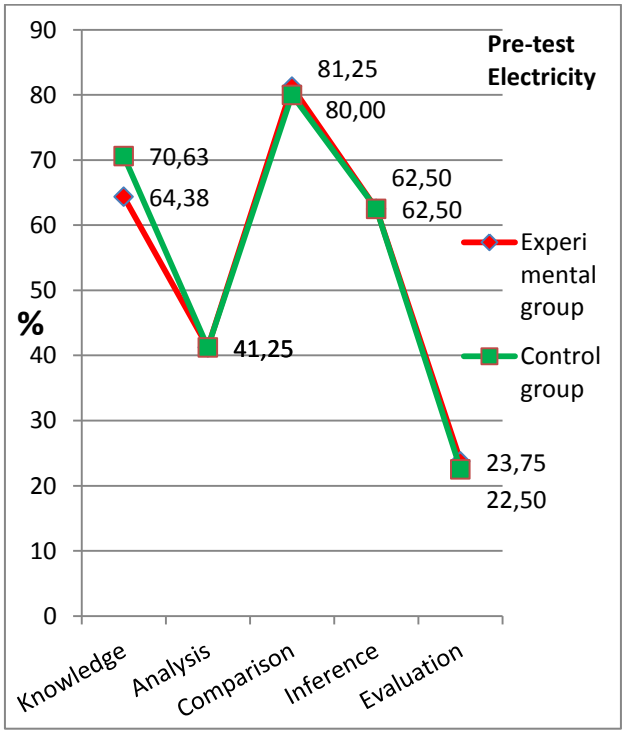

Figure 4: Results of students' tests, in percentages, for each specific thinking skill.

The first thinking skill, Knowledge, is the lowest skill by according to Bloom taxonomy [1], the other four (Analysis, Comparison, Inference and Evaluation) are higher thinking skills.

The results of the pre-tests in the domain of Magnetism are shown in Figure 5.

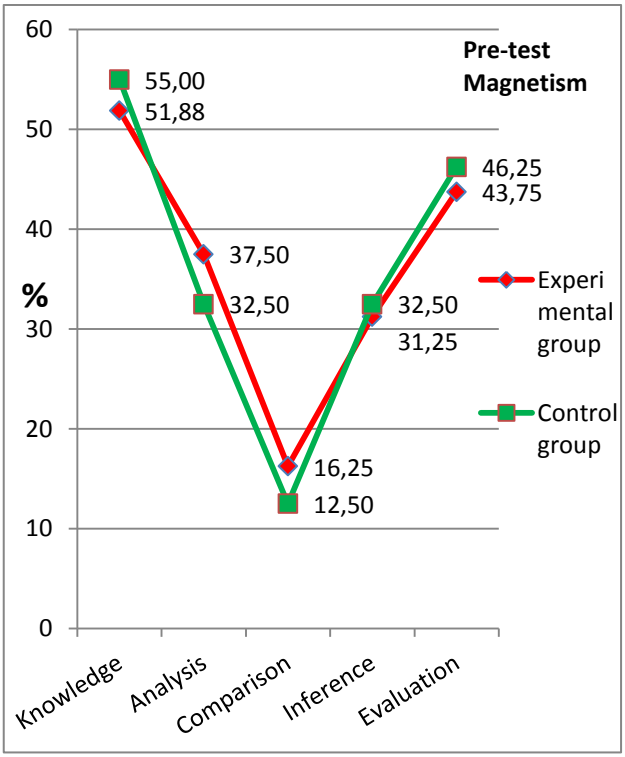

Figure 5: Results of students' tests, in percentages, for each specific thinking skill.

We can conclude from the two graphs that both the experimental and the control group had the same pre-knowledge about the selected topics in Electricity and Magnetism. This factor was very important for our study because we could then attribute the differences in the post-tests results to the efficiency of the specific teaching approach.

3.2 Results of post-tests

After carrying out the lessons on Electricity, students had a written post-test and again after carrying out lessons on Magnetism. The results of both post-tests are shown in Figures 6 and 7.

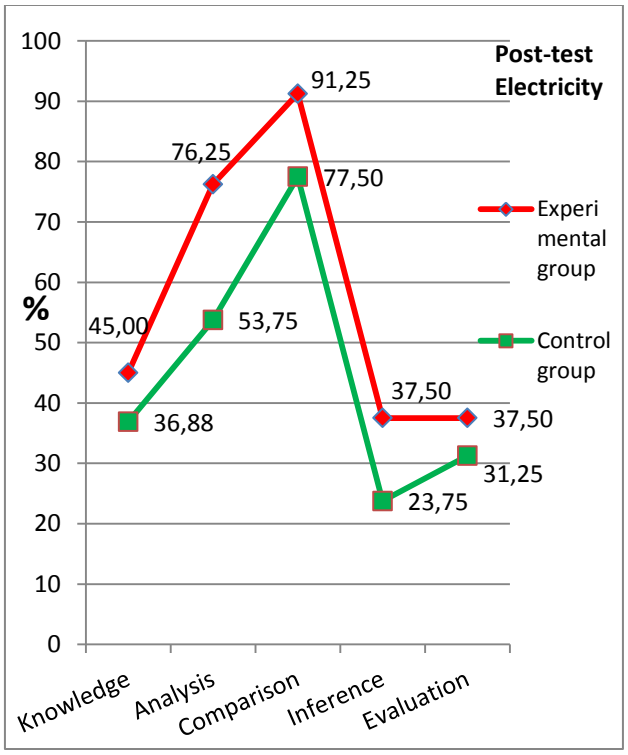

Figure 6: Results of students' tests, in percentages, for each specific thinking skill.

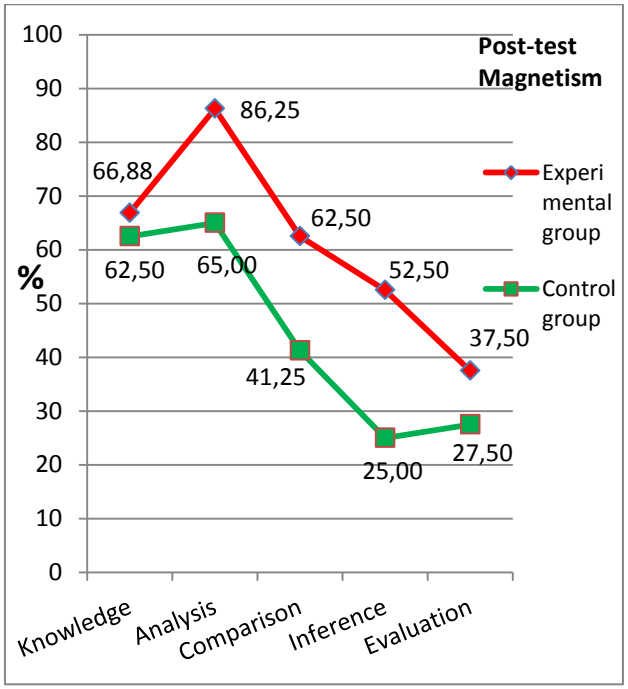

Figure 7: Results of students' tests, in percentages, for each specific thinking skill.

As can be seen from both graphs (Figure 6 and Figure 7), there are significant differences between the results of the students from the experimental group and those from the control group.

The main expected ascertainment of our research was that the students, who were taught through the conceptual way, with emphasize on the usage of the interactive simulations, achieved better results than those who were taught traditionally. So we confirmed that computer simulations could play an important role in the modern educational process.

4. Conclusion

With the rapid progress in the last decade in the domain of computer technology, teachers in secondary schools must think about new, innovative teaching approaches. The lessons should be problem-based and ICT elements should be incorporated. New media and modern, innovative methods lead teachers and students to a deeper insight and better understanding of the phenomena that students learn about. The COLOS project stimulates the exploration of modern technology, especially the great potential of computer models, animations and simulations. The conceptual learning of Physics is a computer based teaching and learning approach with emphasis on the understanding of selected physical law or phenomena. This kind of understanding influences the quality of teaching, improves students` ability to use their abstract thinking and solve problems.

In the conceptual way of learning Physics we used physlets as models. They are interactive materials, where processes happen at certain intervals and there is interaction between the model and the pupil. Physlets enable two-way interaction, and, with the constant possibility of changing the conditions, we can immediately observe the impact of our actions. The applicability of ICT, specifically the computer, in Physics can be seen in the number of didactical examples of physlets, which authors prepare when they systematically cover all domains of Physics.

There are no apparent reasons not to incorporate ICT in the educational process. Empirical data of our research confirms the successfulness of this teaching method.

5. References

[1] Bloom, B.S., (1970). *Taksonomija ili klasifikacija obrazovnih i odgojnih ciljeva*. [*Taxonomy or classification of educational and pedagogical goals*]. Beograd.

[2] Chang K.-E., Chen Y.-L., Lin H.-Y., Sung Y.-T., (2008). *Effect of learning support in simulation-based physics learning*. Computer&Education 51.

[3] Christian, W., Belloni, M., Divjak, S., (2006). *Fizika s fizleti*. *Interaktivne predstavitve in raziskave za uvod v fiziko*. [*Physlet Physics*. *Interactive Illustrations and Explorations for Introductory Physics*]. Zavod Republike Slovenije za šolstvo, Ljubljana.

[4] Gerlič, I., (2006). *Konceptualno učenje in interaktivna gradiva*. [*Conceptual learning and Interactive Materials*]. Informacijska družba IS 2006.

[5] Muller D., Mariaux L., Nicolas A., (1995). *The Colos Project - Applications in the domain of Electrical Engineering*. Proc. of IEEE-APS Symp, Newport-Beach.

[6] Wieman C. E., (2007). Oersted Medal Lecture 2007: *Interactive simulations for teaching physics: What works, what doesn`t, any why*. American Journal of Physics, 76 (4&5).