Computer-Aided Simulations for Hands-on Physics Experiments

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Abstract. *The curriculum for science education both secondary and university level includes laboratory (practice work) experimentations aimed to enhance students' theoretical knowledge gained during lectures and seminars. For this goal school laboratories normally require relatively expensive equipment. Due to economical hardships, the present-day Armenian schools are very poor with technical means of teaching. The shortage of laboratory facilities is an influential factor restricting the advancement of students' hands-on comprehension in science learning. The preset paper is an attempt to examine the opportunities that computers provide in physics teaching practice and to share our experience in this field.*

Keywords. Computer aided instruction, physics simulations

1. Introduction

Armenia was one of the first in the Soviet Union by the percentage of people with higher education. On one hand it was conditioned by the fact, that Armenian industry of the Soviet period was highly technological and science consuming. On the other hand the values of education, knowledge, and professional development were strong and sustainable in society during all periods of Armenian history.

Armenian educational system as all other aspects of economic and social life has largely changed due to the need to adapt to the realities of a market economy in the presence of suppressing economic restraints and uncertain democratic changes. In the meantime these realities impose new requirements and need for educational system and the role of education in the society. Despite the last years' dramatic change in whole economy, the statistics shows that the number of applicants to higher education institutions has not decreased, and the values of education is still very high in Armenian society.

The benefit from the information revolution will depend very much on readiness and capability of country to put in place relevant policies and plans to enable to deploy the power of the Information and Communication Technologies (ICT) to transform its educational system. ICT allow education to be delivered in different ways. They are making high quality technology-based education and training easier to design, develop and deliver and providing the opportunity to educate a greater number of people than was possible before. They promised more than just an improvement in educational productivity; in fact they have potential to deliver a qualitative change in the nature of learning itself. For the first time in history, the world can become a student's classroom through the use of interactive telecommunications such as the Internet. The ICT allows organizing a new progressive and favorable educational environment that can provide our citizens with the opportunities of better access to information, exposure to the Western-type of educational system. The emerging educational technologies, particularly those in the area of ICT are providing new ways of education, training and learning – a window of opportunity to supplement and complement the education and training resources and to support the process of developing an economy based on an advanced and reliable national information and communications infrastructure.

The most current, effective educational solutions based on the possibilities of ICT in education allow establishing a dynamic open-

source educational environment that open wide possibilities for continuing distance and online education.

2. Hands-on physics experiments: virtual vs. real

The continuous growth of ICT allows wide integration of computers in virtually every stage of teaching process. The effectiveness of ICT application in teaching depends upon various factors – hardware, software and teaching techniques used by teacher. A great deal of opportunities appears while applying ICT in physics teaching. Since physics is experimental science in essence, its teaching should be accompanied by hands-on experiments. The curriculum for science education both secondary and university level includes laboratory (practice work) experimentations aimed to enhance students' theoretical knowledge gained during lectures and seminars. For this goal school laboratories normally require relatively expensive equipment. Due to economical hardships, the present-day Armenian schools are very poor with laboratory facilities and with technical means of teaching in general. The shortage of laboratory facilities in most of Armenian educational organizations is an influential factor restricting the advancement of students' hands-on comprehension in science learning.

The emerging ICT are providing an opportunity to improve the situation. Using computer simulations of specific experiments imitating the real physical processes it is possible to somehow overcome the lack of laboratory facilities. The main idea is to use computer simulations at science classes as an alternative of laboratory facilities. Virtually all physics laboratory experimentations can be performed by means of computer simulations.

Computer simulations are integral part of Computer-Assisted Instruction (CAI) that feature live video, sound, animation and interaction. CAI with physics (and generally -science) simulations should comprise introductory theoretical materials, exact description of sequential steps that should be implemented and lead to obtaining experimental data and analyzing them. Surely these simulations should supplement and not substitute the existing facilities.

The effectiveness of these simulations in learning process is obvious – they are cost-effective, they have more demonstrative functions then real practice works and they are absolutely safe. Moreover the simulations allow stepping beyond the limits of ordinary physics laboratories and exploring phenomena that cannot be visualized in any other way.

In computer simulations the CPU imitates the real experimental device; the keyboard becomes a control unit while the monitor combined the digital indicator and a window demonstrating the experiment, displaying graphs, charts, tables, etc. that clarify and enlighten whole process. The computer imitators allow:

- Modeling of physical phenomena under investigation,
- Real-time visualization of experimental device,
- Wide-range modification of technical characteristics of devices and the parameters of experiments.

Surely in order to take advantage of the physics simulation opportunities a well-equipped computer classroom is necessary and as a result expenses on its furnishing could be comparable to the cost of real school physical laboratory. But our experience show that in fact hands-on computer simulations could be effectively integrated into teaching process by means of only single computer with 17-19'' monitor. In this case all students perform the same practical experiment (simulation). Thus the school laboratory facilities based on computer simulations are cost-effective in comparison with the real experimental facilities produced by small series.

Authors keep using computer simulations of some laboratory assignments in teaching practice at different universities and high schools. But most computer-aided ready-made teaching tools are in English or in Russian and therefore certain language problems arise while exploiting them at schools. Besides these teaching materials in general doesn't agree with the curriculum requirements and teaching standards of Armenian schools. To overcome these difficulties we are on a way putting into practice self-designed CAI tools in physics. One of simulations in quantum physics that authors include in their curriculum is available online (see e.g. [1]). The simulation demonstrates a phenomenon (photoelectrical effect) that cannot be viewed visually in any other way but by means of computer imitation. This CAI tool comprise following virtual experiments

- Visual examination of photoelectric effect
- The main laws of photoelectrical effect

- Checking Einstein's theory
- Measuring the Planck's constant

You can take a look on screen snapshot of the photoelectrical effect simulation.

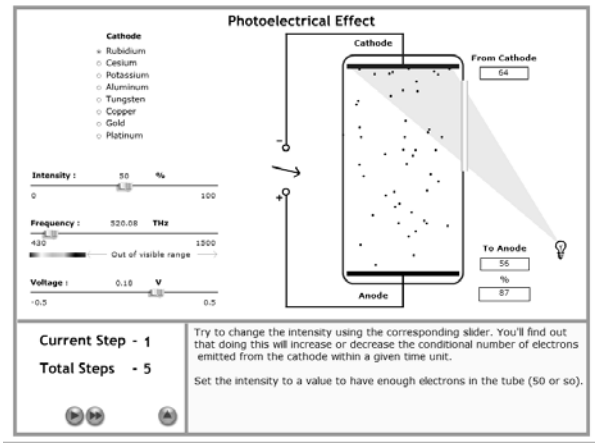

Figure 1. A screenshot of photoelectrical effect's computer simulation.

Instructional language of simulation is English but it could be localized in any language as we used XML format for text information that allow easy modification and/or addition.

3. Discussion

The computer simulations give the instructor wide opportunities to improve the organization of the lesson. He/she can use solely the computer simulations or combine them with real experiments. This is preferable as one hand a good deal of students is willing to do so and on other hand this will offer the students more factual and realistic knowledge about physics experiments.

We carried out an informal survey through our students in order to examine the level of science comprehension after performing computer experiments. Both secondary school (51 respondents from 8-10 grades) and university students (66 respondents from physics and engineering departments) were inquired. The results of survey are introduced in Table 1 and Table 2.

As it is could be seen from the tables most of students prefer the computer experiments vs. the real ones. This ratio is greater for secondary school students. This can be explained by the fact that some of younger students consider the simulations as kind of games and enjoy the process, fan of learning, rather than the understanding of physical phenomena that it offers.

Table 1. Satisfaction level (in percents)

	Secondary school students	University students
Completely satisfied	**59**	**44**
Somewhat satisfied	**24**	**38**
Completely unsatisfied	**17**	**18**

Table 2. Evaluation of knowledge enhancement (in percents)

	Secondary school students	University students
Computer simulation offers more knowledge then the real experiment	**61**	**58**
Real experiment is preferable than the computer analogy	**15**	**22**
It is better to combine both experiments	**24**	**20**

Our experience shows that in fact, computer simulations solely will not give the students the experience and skills of physics experimentalist. More pedagogical outcome can be gained if every student will have opportunity to perform the part of assignment on natural, realistic experimental device and the other part – by means of computer simulation. The first part of the assignment gives the students an opportunity to reveal the casual phenomena and accidental factors that can lead to methodical and unexpected errors or inaccuracy. Thus real physical experiments provide students with understanding that no single physical phenomenon could be viewed in "clear" attitude and thus the result of experiment depends on how successfully the casual, secondary factors are excluded.

We are planning to construct a physics laboratory of CAI and make them available online. Any physics instructor can use this laboratory to boost students' theoretical knowledge since in our time learning is more than just textbooks. It's about exciting new technologies that actually involve students in

learning and that engage students' all senses and brain.

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5. References

[1] Demirjian G. Computer Simulation of Photoelectrical Effect. http://www.gspi.am/demirjian/photeffect.htm

[2] Dzidonu C. ICT- mediated Education and Training within the Context of an Information and Knowledge Economy. Proceedings of the African Development Forum, Addis Abeba, Ethiopia, 24-28 October 1999.

[3] Gomulina N.N. An Overview of New Multimedia Physics Teaching Tools. Issues of Internet Education # 20, 2004 (in Russian).

[4] Greysukh G.I., Stepanov S.A. The Combination of Natural and Virtual Experiments in Physics Laboratory. Issues of Internet Education # 5, 2002 (in Russian).

[5] Kaftrev A.F. Experience of Using Computer Models in Physics Lessons. Issues of Internet Education # 5, 2002 (in Russian).

[6] Patru M. National features of electronic learning. E-learning World #5-6, 2004.

[7] Soefijanto T. A.. Anticipating the New Paradigm of Education. Kompas Daily, May 4, 2004.