PHYSICS LEARNING AND COMPUTER APPROACHES

Jatinder Pal Singh*

Abstract

Physics is said to be a difficult subject. Among the reasons for the learner's difficulties, one has been subject to intense research: the conceptual framework in which students insist to explain the world around them. Nevertheless, there have been more questions arising than answers provided to solve these kinds of problems. We point out the role of computational techniques, namely Simulations, Multimedia, Internet, Virtual Reality, and Computer Based Labs which may deal with those difficulties and increase the learning success. I describe my ongoing experience in the field.

* Associate Professor physics , Pggc-11,Chandigarh

Introduction

Literature review relevant to Computer Based Teaching & learning of Physics by using multimedia at undergraduate level clearly indicates the enhancement of understanding level as compared to the traditional lecturing methods. There was a time when multimedia was considered a very technical venture. Constructive theory also believes that previously acquired knowledge plays an important role to activate the construction process. Results on computer based teaching and learning of physics and investigation of different teaching methodologies were reported by Valiati & Heineck, 2002. Research studies also reflect the improvements of student's learning in comprehension of concepts relative to electric circuits and deepening in how they learn Physics through computer based teaching. Computer based teaching and learning of Physics is a quite common component in the process of education, which includes tutorials, assessment, experiments, data processing and presentation, modeling and simulation .On experiment basis, model lessons/lectures for undergraduate students have developed by covering the leading topics of mechanics, electricity & magnetism optics, quantum mechanics etc and have delivered. Follow-up results clearly indicate increase in learning of physics by the undergraduate students as compared to the traditional lecturing methods.

Problems with Physics Learning and Computer Approaches

The computer allows every student to play an active role in the learning process, in contrast to the passive role of lecture and textbook formats. The student is no longer a spectator, but is an active participant in the learning process. There is a multiplicity of situations to be explored and this can be done at the user's discretion.Individual attention. Teachers know that students are different. Not all students have the same backgrounds and not all students learn in the same way. However, many of our conventional approaches to education use a rigid procedure for all students and do not allow taking these differences into account. An advantage of the computer is that, with good software, it can individualize instruction. Furthermore, as all students do not learn at the same rate, different students need different times to go through the learning material. The computer also allows that. These ideas helped to abandon an initial stage of computer use in education, in which computers were basically tutorial machines running software which was designed to "program" students according to some fixed scheme. Bigger interactivity and feedback were needed to respond to the modern pedagogical theories.

Another important factor in the advance of computer use in education was that computers quickly became more powerful, therefore more and more suitable to implement new ways of learning. They got more rapid central processing units, taking advantage of the enormous miniaturization, more memory, both central and backup, and all this was provided at less cost. Graphic capabilities have improved considerably, allowing for full animation, realistic three-dimensional images, etc. A landmark which helped to democratize computers was the appearance of the personal computer in the late seventies.

Different Ways of Using Computers

We may distinguish different ways of using computers for teaching and learning Physics [4,24]:

Simulations

Simulation has been probably the most explored field. We talk about simulations when we run in the computer a model of Nature. Sometimes the word modelization is used when the emphasis is on building, i.e., programming the model, while simulation is left for the situation when the model is considered a "black box". This distinction is somewhat artificial and not always clear. Since the laws of Physics are expressed by differential equations, it is normally easy to implement a simulation for a given physical problem: this may be for instance the free fall of a stone, the orbital motion of a planet under the influence of one or more stars, and even the collision of two galaxies. However, simulations may also be made when we do not have a differential equation but an iterative relation: that is the case of the logistic map, a difference equation used in introductory studies of chaos.

Simulations should never entirely replace reality but are extremely useful when we have to study experiments which are impossible to do in practice.

Multimedia

This modality is based on the concept of hypertext or, more in general, hypermedia. The word multimedia means that modules include a variety of elements, such as texts, images animations, simulations, and video clips [28]. The motto is "an image is one thousand words worth" so that the information should be as visual as possible. An hypertext module has several internal links and a reader does not need to follow a linear or sequential path through the module but, based on his experience and interests, may easily select those parts of the module that are of interest to him at the moment. Other links will enable users to move efficiently between different modules. Essential features of multimedia are interactivity and flexibility, i.e., the possibility of entering commands and the ability to choose a path within the provided information. Since, according to some pedagogical theories, these factors are required for good learning, the educational advantages of multimedia have been widely advocated. The defenders of multimedia say that it is the convenient format for learning due to the fact that our brain processes information by free association of concepts in a intrinsically non-linear way. However, the sequential way, which still presides to the organization of most courses, seems to be more adequate for systematizing contents. Multimedia may be on-line or off-line depending on the way that information is offered. A connection between these two supports is nowadays easily made. Multimedia off-line did not undergo the big explosion it has been announced, perhaps due to the enormous progress of the on-line format, which is mostly free. Like other multimedia products created for science learning, it includes several interactive simulations. Although the success of multimedia in science education has been restricted so far, its role in motivating students should not be disregarded. Even before the conceptual difficulties of the students emerge, lack of motivation for studying science may be the main cause for failure.

Internet

The Internet, the network of all networks, has known a big success in the society in general and in schools in particular [25]. Its use for science teaching and learning shows still a big potential in spite of the amount of interesting work already done. Computer use in a network includes playing with simulations (these may be downloaded from the net or simply explored on-line if they have been written in the Java language), multimedia and Virtual Reality Let us look at the way in which Internet is changing our teaching and learning styles. In the prevailing education model, the teacher plays the main role, determining the pace of learning. Taking advantage of new technologies, more interactive and more personal learning may be implemented. The teacher should then help the student in a different way, for example in searching and selecting information relevant to a given goal in the middle of the enormous and disordered information oceans. Under these circumstances, his role will be no more central to become peripheral.The teacher will no more be the information's single owner and provider to become an expert and consultant for discussing matters and solving problems. The World Wide Web became the biggest and the most lively of all libraries and the classroom walls have been demolished with the direct link to that source.

At the same time, the Internet represents a big step towards a bigger democratization of education, with equal opportunities being given to every student, independently of its geographical situation. Many courses exist on the Web and may be accessed by everybody from everywhere.

Sometimes, it is not only the aspect of the course but also the contents, which are new. Let us consider an example of revolution in learning contents which is being presented on the Web. One of the features of present education is the compartmentalization and specialization of instruction by departments and even by subgroups within departments. While this is understandable, and even necessary to some extent, it has the effect of obscuring the connections between different fields. For example, students in Mathematics classes often do not know how Mathematics is applied in engineering or science. At the same time, students in engineering or science courses repeatedly fail to recognize that the ideas and methods they learned in calculus or linear-algebra classes are what they need to solve problems they are bind. Some universities have begun to explore other ways of organizing the education of scientists and engineers. For example, the "Mechanics, Linear Algebra, and the Bicycle" module is not designed to teach everything about mechanics, linear algebra, or bicycles. Instead, the module is meant to be a guided tour through some concepts of mechanics and related mathematical techniques, namely vectors, matrices, and sets of linear equations.

The module intends to draw on a student's interest in understanding how and why a bicycle is made the way it is. The module offers opportunities for a student to learn about mechanical and mathematical details, being its main theme is the link between mathematics and engineering in physical models. As a graphical demonstration, there is a Java applet that allows a student to create new bike shapes in two dimensions.

On the other hand, the "Differential Equations and Mechanical Oscillators" module is directed towards the study of mechanical oscillators. The first approach is analytical and conceptual. Assumptions based on engineering are used to reduce the actual physical system to a simple model. Then, application of the laws of Physics leads to a mathematical model, which consists of a system of one or more differential equations taken together with initial conditions.

Virtual Reality

With Virtual Reality the focus of learning is placed in the conception of environments that allow students to interact with the computer with minimal restrictions [29]. According to Papert [26], a good learning environment requires free contact between the user and the computer. The reduction of the interface is precisely a necessary condition to immersive Virtual Reality. Two important implications result from immersion. First, there is a smaller distinction between the user (student) and the computer information [23]; second, immersion allows for a non-symbolic interaction with the environment.The main characteristics offered by Virtual Reality to education are immersion, interactivity and manipulation.Virtual Reality brings together a set of characteristics that make it a unique technology as a learning means: Virtual Reality is a powerful visualization tool to handle 3D problematic situations. Virtual environments allow learning situations by trial and error that might encourage students to explore a wide choice of possible solutions. The student is free to interact directly with the virtual objects, allowing first-hand formulation and verification of hypothesis. The virtual environment can offer adequate feedback, allowing students to focus their attention on specific conceptual errors. Virtual Reality can collect and show complex data in real time. The immersive nature of Virtual Reality can endow students with extra capacities to retain information.

Computer-Based Laboratories

Physics is an experimental science and the computer found already a place in the Physics laboratory. The richness of Computer-Based Labs and associated modeling tools could have a major impact on physics teaching and learning.We can use these tools to make Physics far less formidable for students with low mathematical abilities. We can use them to place more emphasis on intuition, and, at the same time, to give students the ability to solve complex problems.

Perhaps the most important possibility created by this technology is that it allows students to undertake their own original investigations. Much of what is wrong with science education is that students usually only learn about science: they do not participate in a meaningful way.

Students at every level should have an opportunity to do real Physics experiments, to participate fully in learning new facts about the natural world. Hands-on participation provides not only a strong motivation but, more important, is the only way to give students an accurate understanding of science, whether their careers will lead them into science or not.

Learner-controlled explorations in the Physics laboratory with real-time measurements give students immediate feedback by presenting data graphically in a manner they can understand. Using sensors and software, students can simultaneously measure and graph physical quantities such as position, velocity, acceleration, force, temperature, etc. Those tools provide a mechanism for including in Physics teaching methods, which are found effective by educational research to deal with conceptual difficulties. The ease of data collection and presentation encourage students to become active participants in a process, which leads them to ask and answer their own questions. The real-time graphical display of actual physical measurements directly couples symbolic representation with the corresponding physical phenomena. Moreover, the comparison of real data with simulations is a very rich pedagogical tool.

Understanding the basic concepts of physics

Students' experience with the world has led them to construct a set of beliefs about how the world works. Students misunderstand basic ideas of physics, in part because of their previous experience and in part because of the way we use language. In addition, "common sense" speech and reasoning are "fuzzy". Similar concepts are not differentiated, resulting in confusions that seem bizarre to a physicist who is accustomed to precise reasoning and operational definitions. It has been demonstrated by extensive PER experiments that a majority of students entering a typical calculus-based physics class do not understand the meanings of velocity and acceleration,[9] fail to distinguish force from momentum [10] fail to distinguish heat from temperature, and retain rigid and inappropriate beliefs about the nature of light, images,[11] and electric currents.[12] Furthermore, the student's success on typical "end-of-the-chapter" problems has little correlation with developing an understanding of the deeper concepts.[13]

Knowing what science is and how it works

In addition to problems with the basic concepts of science, students in introductory physics courses often have deep misunderstandings of the nature of science. They often have little idea about how science works or how one does it. Not only do many students get the basic concepts of physics wrong; their very idea of how science works and how knowledge is obtained is often wrong.

Many students fail to distinguish mathematics from physics and hypothesis from experiment.[14,15,16]

Many students do not understand the kind of knowledge we expect them to build nor the kinds of skills we expect them to develop.

Many students do not understand that science is fundamentally open and non-authoritarian.

Many students do not understand that science is fundamentally approximate and inexact.

Many students think that scientific knowledge is absolute and must be taken from wiser authorities.

Many students think that physics is a collection of unrelated pieces that have little to do with the everyday real world.

The activities of a typical introductory class do little to disabuse our students of these deep structural misconceptions.

Conclusions

After briefly referring to the conceptual difficulties in learning Physics, I have focused on the role of computer technologies to deal with them. I have classified the different uses of computers in Physics, besides the more trivial ones. My division was schematic, since each type of use cannot be completely separated from the others. Simulations and Multimedia have already been much explored, in some cases achieving visible success for learning but also knowing some insuccess.Internet, Virtual Reality and Computers-Based Laboratories seem to be the more promising fields. They need to be further and better explored. We are not able to anticipate the future in this fast evolving domain. Probably new uses will be added to our list. For instance, nowadays the immense computer power of the Internet is being underused. Cooperative work with students participation taking advantage of that computer power to solve real scientific problems is a possibility that is starting to be explored. Science Education can only gain from being close to science.

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