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This article presents an interactive environment for simulating physical phenomena and experiments for students of Education Department for Primary School, as well as the first results. A computer environment is proposed where students themselves are able to build their own experimental simulations in mechanics, and to interact with it.

Computers have been involved in the education process since the appearence of the first systems such as mini and personal computers. Computer Based Instruction (CBI) and Computer Aided Instruction (CAI) are the two main ways in using computer science in all levels and disciplines in education. In the particular case of science education, studies on cognitive mechanisms have led to a scientific approach for the transfer of Knowledge and the teaching of problem solving and other intellectual skills (Reif 1981).

Advances in information processing psychology, linguistics and Artificial intelligence have changed the way people think. Furthermore, advances in computer science have given new tools to education (Reif 1986). To get to the point in science education, and especially problem solving, Reif describes some central issues, which are the following (Reif 1986):

«The interpretation of scientific concepts, organization of knowledge, and principled instruction. The above three, are main characteristics of Information Technology. Concerning for example Knowledge organization, its hierarchical structure has led to much better performance of students than the linearly organized knowledge. Hierarchical organization is a main characteristic of computing science not only in software development, but also in the structure and presentation of software tools and ready to use applications».

Physics, and especially physics education, is one of the sciences where information technology (IT) has found a wide field of applications. This is because physics deals with the laws of nature and how everything acts, has an experimental nature, and it is difficult for someone to perceive and understand its concepts and reach the level of problem solving.

Progress in information technology and the involvement of computer systems in academic and research institutions where teachers and students can have access to them, has changed the way physics is taught and presented to the students.

Physics curriculum, teaching environment and the skills students have to develop are continuously changing, and computers have allready found their role as a pedagogical tool.

Concerning curriculum, four main principles have to be considered (Martin et al 1991):

– a high-level programming language for the students to be in command of information technology

– acquisition of problem solving skills

– stimulation of the reorder and broadening of the subject taught, the building of physical intuition and the pursuit of independent study

– the decoupling of physics learning from its mathematical formulation.

Teaching environment involves the means of improving the current teaching, the development and testing of innovative approaches and new learning environments (Wilson et al 1992). Concerning skills, computers can help students to understand fundamental physical concepts, learn contemporary topics and provide experience with complex systems.

Computers in physics education can be used in many ways, such as: course management, tutorials, practice, testing, programming, laboratory data acquisition, modeling physical phenomena, simulations, expert systems, and interactive environments.

The introduction of IT in physics teaching has also arised from practical issues. Among these are difficulties in the understanding of the concepts of velocity (Trowbridge et al 1980) and acceleration (Trowbridge et al 1981) from student populations coming from different disciplines, physics students' preconceptions in introductory mechanics (Clement 1982), student difficulties in connecting graphs and physics (McDermott et al 1987), and much more.

Alfred Bork in the Millikan lecture, posed the aspect of interactive learning through computers, where students become participants in the teaching process rather than spectators (Bork 1979). Many educational environments have been developed towards this direction. Computer tutorials and demonstration programs including simulations of physical phenomena run in academic institutions. These include some basic characteristics of interactivity where users can change constants and parameters, see and judge the new results (Cook 1990).

A different approach includes the microcomputer-based laboratories where computers are used for data acquisition and students have the chance to manipulate them using spreadsheets, mathematical, and presentation tools (Thornton 1987). Wilson has presented an interactive computer system where students are familiarized with experiments in modern physics by using graphic computer simulations of laboratory experiments prior to each practice in the lab (Wilson 1980).

Much of the research on computer uses in physics teaching concerns science students. To our knowledge, only few such as Ronald Thornton address to non science majors with his microcomputer-based laboratory by using a motion detector in order to measure, display, and record the distance, velocity and acceleration of objects (Thornton 1987).

This work presents an interactive environment for simulating physical phenomena and experiments for students of Education Department for Primary School, as well as the first results.

The non-science students

University level students have fundamental misconceptions regarding the laws of nature and the way they can be used in problem solving. This holds even for science students with obligatory physics courses in their curriculum. The problem becomes more intense for non-science students and more serious for students of Education Departments. These departments prepare students to become teachers mainly in elementary and secontary schools. In the Department of Primary Education, the study of the physical world is an important topic, since it is taught in 8-12 year-old pupils with no or some naive knowledge of the world. The problem of understanding physics for this kind of students begins in the secondary level of their education where they do not get physics courses or they have no interest in them, and continues at the university level where usually physics courses are not obligatory.

The weakness of non-science students to be involved in physics, includes various aspects. Used to studying in a specific way their material for disciplines accessible to them, they are unable to use and understand science textbooks. Moreover they feel problem solving as an ideological problem and skill difficulty (Tobias 1985).

In the Greek educational system, secondary graduates have to pass national exams in order to follow university level studies. Almost three years before the end of highschool, pupils choose the subject of their future studies giving more interest in relevant courses. The final year of highschool consists of separate batches of courses depending on the kind of the university studies they wish to follow. Students in departments of primary education come mainly from batches of courses with complete lack of physics.

Computers in physics teaching

Any science learning in all levels of education is mainly based on lectures, laboratories and homework concerning problem solving and data manipulation. Experimental results have shown that lecture-based courses especially for a large audience, in spite of their advantages, have the main disadvantage of poor information conveyance (Bork 1979). Moreover, they do not include individualization, an important factor considering education, but they are common for any member of the audience. CAI helps towards this direction using tutorials, drills and simulations. These apply pedagogical principles such as mastery learning, direct instruction, memorization skills, learning styles and transfer of learning. In this way, students can understand the topics covered by the textbooks and may be able to solve the problems of each chapter. This does not mean that students acquire knowledge and intuition of the physical world and can apply the theories they know well into other relevant topics. They do no science, they have no experience of the discovery, building, testing and modifying models. The understanding of nature without misconceptions and physics intuition becomes more important to students of Departments for Primary Education. They have to teach a variety of disciplines and physical sciences as a whole among them. So, they have to know their interconnections and the influence of physics on other sciences such as biology and chemistry. They have to be ready to answer to the usual questions of young people concerning the world, and explain its operation with simple thoughts. Moreover, the teacher with an understanding of the general principles of physical phenomena, helps himself regarding other disciplines such as biology and psychology. Problems in these subjects are solved using the rules of the scientific method which are posed by physics (Vergados 1988). Physics helps other sciences with an essential way by giving them the basic concepts they need (time, velocity, force, energy).

Concerning laboratory experiments, their value is obvious in the educational process. In physics education, they are important for the students in order to acquire empirical experiences in learning skills and concepts, doing science. On the other hand, the disandvantages of laboratory experience seem to be enough to discourage both educators and students. Laboratories which follow lectures are rather places for developing skills and not for learning physics concepts. Usually, data processing, discussions and conclusions concerning the laboratory experiments take place after the end of the experiments, out of them. So, there is no chance of controling the working environment, testing and evaluating data, and modifying conditions and parameters. That way, some of the interactivity of the laboratories is lost. Moreover, laboratory equipment is mainly expensive, dangerous, hard to use and unreliable. Problems of this kind are partly solved by the experimental simulation in the modern physics laboratory (Wilson 1980) and Ronald Thornton microcomputer-based laboratories for physics teaching (Thornton 1987). Both works are connected directly with laboratory experience.

The experimental simulation

The present work concerns computer physics simulations for non-science students. Its emphasis is not on the exact simulation of some experiments in order students to be familiarized with the laboratory environment, techniques and skills. It is on motivating students to connect physical phenomena, scientific concepts and their representations in order to acquire a clear understanding of the physical world without misconceptions, to be able to solve problems, and to transfer their knowledge to their future pupils. The main difference of this article from Wilson's experimental simulations is that his work is directly connected with the modern physics laboratory, it simulates experimental data including data analysis, graphical representations of related variables and answers to questions. Our approach to physics simulations is in the sense of Frank Smith Jr., who used a personal computer in lectures to provide simulations of motion (Smith 1990).

We propose a computer environment where students themselves are able to build their own experimental simulations in mechanics, and to interact with it.

Having this in mind, we choose Interactive Physics 1.2 of Knowledge Revolution as the software tool which runs in Macintosh microcomputers.

It is reviewed by A. J. Mallinckrodt (Mallinckrodt 1991) and we will give only its basic characteristics. Interactive Physics is a computer-based laboratory that simulates the mechanical behavior of objects in two dimensions. A reason of choosing this tool is the simplicity of data input and output which are graphical. The user draws the experiment and its initial conditions, and the software calculates and displays the consequent action as an animation in accordance with Newton's laws using a fixed time-step numerical integration method. The user has the chance to adjust some properties of the two-dimensional world such as its size, gravitation field vector and air resistance. The specifications of mass objects can be set by the user too. Interactive Physics provides a tracking option which gives a stroboscopic picture of the experiment. Data collected during the experiment can be exported in a data analysis program for later analysis. The software as a numerical simulation gives some unphysical artifacts that result from the fundamental limitations of its algorithms. Some problems may be arised in complicated experiments. In spite of this, the algorithm is adequate for simple projectile motion simulations, and this is enough for the present work with its main aim being the understanding of fundamental physical concepts such as linear motion, velocity and acceleration.

Results and discussion

This work is a case study. The respondents to the project were seven students from the Department of Primary Education, University of Ioannina. Table 1 shows their history regarding physics courses and computer experience.

STUDENTS	SEX	YEAR	PHYSICS		COMPUTERS	
S1	M	4	2	2	0	0
S2	M	1	1	1	2	WS, B
S3	F	1	0	0	2	WS, B
S4	F	4	4	4	0	0
S5	F	4	0	0	2	WS, B
S6	M	4	0	0	0	WP
S7	F	4	0	0	2	WS, B

Table 1. *History of the respondents. M: Male, F: Female, YEAR: Year attended PHYSICS: Number of physics courses (theory, laboratories), COMPUTERS: Computer sciene courses (classes, experience), WS: Microsoft Works, B: Basic, WP: Word Processor.*

The first thing students were asked to do, was to answer to five simple questions concerning the understanding of every day physical concepts.

These are the following:

1. Give the definition of the physical quantities of mean velocity and acceleration.

2. What do velocity and acceleration mean? Give explanations in your own way using experiencies of every day life.

3. Describe the velocity change of an automobile.

4. Does the mathematical expression $\Delta v/\Delta s$ remind you of any physical quantity? Does it have a physical meaning?

5. Have you ever seen 10m/s/s in vertical throw? What does it express?

Concerning velocity, all students gave more or less the same, right definition, two of them used the formula $v=\Delta s/\Delta t$, and the rest ones, $v=s/t$. Moreover, only two stated that velocity is a vector. All but one (S6) definitions show that students believe that velocity proceeds the idea of $\Delta s/\Delta t$. Only S6 stated that «velocity comes from the idea behind $\Delta s/\Delta t$» and follows A. Arons rule «the idea proceeds the name» (Arons 1990). Looking at the formulae, it is shown that respondents use both $\Delta s/\Delta t$ and s/t to declare the same thing. This is a problem becaue symbols s and t have a different meaning in equation $s=at^2/2$. For the definition of acceleration, three students confused the term «quotient» with «duration», and didn't understand its connection with the time unit. Table 2 shows answers to the second question, with five students to confuse the velocity with other

STUDENS	VELOCITY			ACCELERATION		
	DEF	FORMULA	CONFUCE	DEF	FORMULA	CONFUSE
S1	+	$\Delta s/\Delta t$	motion	?	$\Delta v/\Delta t$	montion
S2	+ (v)	$\Delta s/\Delta t$	time	+ (v)	$\Delta v/\Delta t$	-
S3	+ (v)	s/t	no answer	+ (v)	$\Delta v/\Delta t$	no answer
S4	+	s/t	smace	+	$\Delta v/\Delta t$	-
S5	+	s/t	-	?	-	no answer
S6	+	s/t	space	-	v/t	velocity
S7	+ (v)	s/t	time	?	$\Delta v/\Delta t$	no answer

Table 2. *Anwers to the first and second questions.*
DEF: Definition, (v): vector, ?: not clear.

quantities and the rest ones give no answer. Concerning acceleration the percentage of confusion is less, and this is may be because almost all physics textbooks present the acceleration as $\underline{a} = \Delta v/\Delta t$. Some of the students gave examples from every day life. Concerning the concept of acceleration there was a misconception. Almost all the students wrote about the rate of velocity change, or referred to a relation between velocity change and a period of time, not clearly showing it. Two students (S3, S5) used the term acceleration as a growing of the velocity, declaring the naive understanding of the concepts and not an accurate one, something that is notified by Trowbridge and McDermott who showed that students have difficulties in changing these misconceptions even after some physics lessons (Trowbridge 1981). Only one respondent (S4) wrote that acceleration is the quotient of the two relevant quantities.

In third question two respondents (S3 and S7) didn't give an answer, and the others gave examples with cars giving values at their velocities in order to explain the velocity change. Again there were confusions with space and time, and nobody mentioned acceleration.

The idea of $\Delta v/\Delta s$ comes from Galileo and was posed as a motive to the students for an alternative way to describe a physical concept. Six students stated that $\Delta v/\Delta s$ didn't remind them of anything and they were absolutely sure that it has no physical meaning. Only one (S4) wrote that it has been used as a definition for acceleration.

Answers to the fifth question show that students in general can't combine and can't recognize a physical quantity from its value and units. More specifically a student (S7) gave no answer, another one (S3) said that he had never seen it before, and only two of them (S1 and S4) wrote that it is the approximate value of the gravitational acceleration on earth. The rest of them weren't sure what 10m/s/s is. From the five questions it seems that students gave responses based either on textbooks or on what they remembered from secondary school. As table 2 shows, there are misconceptions concerning velocity and acceleration for both groups of students, those who had taken physics courses together with labs, and those who hadn't. This is an indication that even laboratory experiments didn't remove misconceptions on simple physical ideas.

After the above written test, an introduction to interactive physics followed. First there was a short tutorial with some demonstrations, and next day students had two hours to be familiarized with the software, two students sharing a macintosh. Although half of the respondents had no special interest in physics, all of them were enthousiastic about the «world» they faced. After the familiarization with the environment and its tools, students started to explore several capabilities. So they perceived the concept of elasticity through the jumping of a ball falling on a steady level. They also tried to build a pendulum and to put it in motion. Others, designed an inclined level and since the environment didn't give them its angle, they tried to calculate it recalling trigonometry. All these, show that humanities students found a motive through the simulation of the Newtonean world in order to explore and understand physical phenomena.

The third step of the study included a series of three experiments on uniform, linear uniformly accelerated motion, and vertical throw which students had to simulate in the computer. Properties of the world and initial conditions of the objects were given and students answered to few basic questions concerning the run of the experiments and the evolution of basic physical quantities. After that, they made the simulations and used the software tools, got measurements, made graphs and plots, and recorded the time flow of the experiments in order to understand the relevant concepts where this was necessary. With the end of each simulation, students had to answer to some questions not only on the concepts of velocity, acceleration, and kinds of motion, but also on the proper simulated instruments for each specific study and the values of certain quantities in the evolution of the experiment.

The first simulation was on uniform motion.

All students realized that they had to use the meters of space and time in order to calculate the velocity and made the proper table. Students found out the necessity of getting many measurements for the velocity calculation to be accurate. They also saw that velocity was constant, something that they had expected. All respondents explained that there was no acceleration because of this. Two of them (S1, S3) looking at the initial conditions, notified that there was no acceleration since they didn't apply any force to the object. When they were asked to make the graph of space as a function of time, all but one (S4) used the horizontal axis for space. In spite of this, all of them found the way that velocity comes from the graph. Concerning the plot describing the phenomenon, all the respondents made the graph of velocity as a function of time with the correct line parallel to the horizontal axis showing that velocity was constant.

In the graphic simulation on rectilinear uniformly accelerated motion, students run the experiment using the tracking option as shown in figure 1. From this, all of them felt the change of velocity, made the graph of it as a function of time, explained the concept of acceleration, and calculated its value. Besides, three of them (S2, S3, S7) wrote down that acceleration comes from $\Delta v/\Delta s$, probably looking at the track of the object and watching

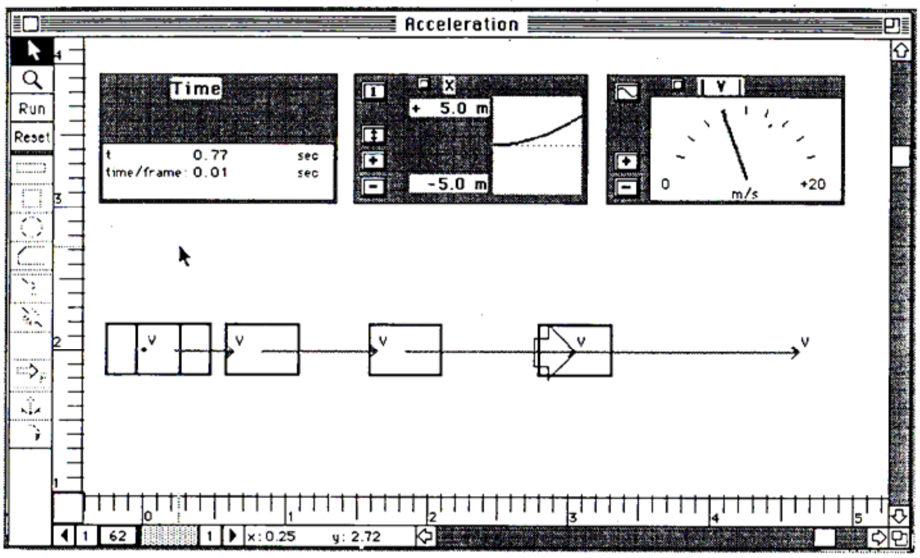

Figure 1. A part of the rectilinear uniformly accelerated motion in tracking mode.

that as velocity goes higher, it moves longer distances in the same periods of time. All the respondents noticed the velocities used during the motion were the momentary ones, something that it is not clear enough in lectures.

In the last experiment on vertical throw, all the students analyzed the motion in two parts, one retarded (way up) and another one accelerated (way down). A question students had to answer was to draw one or more arrows showing the direction of each force acting on the object on its way up. Students S2, S3, S5 and S7 answered correctly. The rest of them drew an upward arrow referring to it as the «force of the throw» or the «force up from velocity» which is a common error even for engineering students (Clement 1982). This shows that the «motion implies a force» preconception was involved in the respondents' responses. After the graphic simulation showing the forces acting on the object and a short discussion among students, this misconception was cleared up and all students understood the reality.

In another question concerning vertical throw with an initial velocity of +30m/s, and the simulation in the tracking mode, students had to find the velocity at the end of the first, second, third, and forth second. All students gave the right answer. For the third second they notified that the value of velocity was 0m/s and that of acceleration different from $0m/s^2$. This is an important step towards the understanding of momentary quantities and the elucidation of the discrimination between the concepts of velocity and acceleration, something that the respondents confused in the written test before the simulations. Two students (S1, S3) said that this value is for $t \rightarrow 0$. The others said that this is for an extremelly small period of time.

With the end of simulations students had to solve some simple problems using data from the experiments and making graphs regarding the uniform motion and vertical throw, and explaining the kind of motion represented in some graphs. As McDermott showed (McDermott et al 1987), students had difficulties in connecting graphs and physics. Realizing their difficulties, the respondetnts wished to repeat the simulations in tracking mode, recording the values of specific quantities. After that things became clear and major misconceptions were cleared up, it became evident that the direct feedback is one of the main advantages of the experimental simulations in relation to the laboratories.

In the next step students had to answer to theoretical questions similar to those ones before the simulations and table 3 shows the answers. As one can see, all students gave the right definitions. Almost all of them wrote the mathematical expressions, and even those who wrote that v=s/t, ment $\Delta s/\Delta t$ as they explained in written. All the respondents stated clearly that the two quantities are rates and can be expressed by a quotient showing that here are neither misconceptions, nor confusions with other quantities. Concerning $\Delta v/\Delta s$ three students (S4, S5, S6) wrote that it has to do with acceleration, a conclusion from the graphic simulation, and tried to express it using this formula. For 10m/s/s this time all students gave the right answer.

STUDENTS	VELOCITY			ACCELERATION		
	DEF	FORMULA	CONFUSE	DEF	FORMULA	CONFUSE
S1	+	$\Delta s/t$	-	+	$\Delta v/\Delta t$	-
S2	+ (V)	$\Delta s/t$	-	+ (v)	-	-
S3	+ (v)	$\Delta s/t$	-	+ (v)	$\Delta v/\Delta t$	-
S4	+	s/t	-	+	$\Delta v/\Delta t$	-
S5	+	s/t	-	+	$\Delta v/\Delta t$	-
S6	+	s/t	-	+	$\Delta v/\delta t$	-
S7	+ (v)	s/t	-	+	$\Delta v/\Delta t$	-

Table 3. *Answers after the graphic simulations. DEF: Definition, (v): vector.*

In a few words, respondents' answers showed that some misunderstanding and misconceptions were cleared up after the experimental simulations.

The final step of the study was a general questionnaire regarding the respondents' opinion on CAI and computer use in the educational process. Questions had to do with the following subjects:

Understanding of physical concepts and more positive way of thinking for problem solving.

Physics using computer simulations.

Learning physics using computers.

Interest in the laws of nature through simulations.

Comparing laboratories and computer simulations.

CAI in other disciplines.

General interest in computers.

All students viewed computers as a powerful tool not only in the specific subject, but also in other topics and disciplines. The respondents as future educators had the possibility to see pedagogical principles to be marked out and work using the computer. So, after the simulations in their answers they mentioned direct instruction, overlearning, memorization skills, prerequisite knowledge, immediate feedback, peer tutoring, cooperative learning, and transfer of learning. All these, were realized using the computer, something that they have not seen with the classical teaching techniques.

All students mentioned the limitations of textbooks (style of writing, linear text) and lectures in comparison with computer simulations which contribute to understanding and consolidation of concepts with a fast, pleasant, and complete manner. Comparing with laboratory experiments, they prefer the combination of the two. With the simulations they had immediate feedback, the chance of varying the parameters of the experiments any time, even those which are impossible in the lab such as the parameters of the world. They also could see the act of vectorial quantities on the objects. Among the advantages of the lab they mentioned the experience with real instruments, and all of the students think laboratories as a place for the development of skills rather than a means for understanding physical concepts without misconceptions. Some of the respondents expressed the idea for microcomputer-based laboratories. Students, especially those who haven't taken physics courses liked the way physics was presented to them through the computer, and started to be interested in the laws of nature and found a good reason to get physics courses.

All students found CAI as a necessity in all disciplines giving examples like that one on biology. Without having previous experience in computer uses in education, they mentioned things that are materialized with animation, simulations, and hypermedia. The respondents saw by themselves the meaning of computers in education as future educators, noticed from their experience in the project that children can understand the meaning of their acts using computers, and made proposals for the introduction of information technology in schools.

CONCLUSIONS

Among the goals of the present work are these ones referred by Gabel and Boone (Gabel and Boone 1993), that is to srengthen students' conceptual understanding of science, deepen their knowledge of the nature of scientific inquiry, and enhance their ability to use technology in learning and teaching sciene. These are coming from the results of the work which helped students make explicit connections between physical phenomena, scientific concepts and their algebraic and graphic representations. We believe, that the kind of graphic simulations presented in this work, enabled the students to discover for themselves the limitations of an Aristotelian framework, as well as the far-reaching explanatory powers of the Newtonean paradigm (Champagne et al 1980), and give them a strong belief in themselves as future teachers without having had a great deal of exposure to computers.

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