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Students' Performance towards Computer Simulations on Kinematics

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ABSTRACT

This article presents the effects of computer simulations on students' alternative conceptions about the concepts of velocity and acceleration. Firstly, we investigate and identify students' ideas and cognitive constraints exhibited in the research tasks concerning the kinematical concepts. It seems that students faced various difficulties and confusions between velocity-position, instantaneous-average velocity, and velocity-acceleration. Secondly, we evaluate the contribution of simulations we have created using Interactive Physics to students' meaningful understanding of simple kinematical phenomena and developing of mental representations. The interpretation of our results indicates that computer simulations can assist students to overcome their cognitive constraints originating from their believes about the concepts of instantaneous velocity and acceleration.

INTRODUCTION

Physics teaching, as well as Science teaching in general, is a concessive field for designing and developing educational computer applications. Today various types of computer applications are available for teachers and students, such as computer-based laboratories [1], spreadsheets [2], multimedia [3], simulations [4], and intelligent tutors [5]. They express different educational approaches and cover various educational needs. The use of such tools has been leaded into a new research field for Physics Education, since it radically changes the framework under which Physics teaching is integrated.

Computers allow students to work in conditions that are extremely difficult to be created in the classroom or in the traditional physics lab. Thus, the number of physics topics one may deal at school is increased, since the possibilities of representing physical phenomena are extended. From another point of view, a closer examination of Science problems of a special methodological type becomes possible. Such problems could be the hypothesis control, the consequences of the initial conditions' alteration, the study of stroboscopic representations hardly accomplished in the lab, and the simultaneous use of multiple representations about physical processes and phenomena (pictorial, graphical, symbolic).

A vast domain of the research on Physics and Science Education aims at two directions [6, 7]. The first is the detection of the alternative conceptions of the students at various ages. This deals with students' mental representations about concepts and phenomena, not only before but also after the classroom instruction, that are not compatible with the relevant scientific models. The second is the study of the results of special teaching interventions, aiming at the transformation of the students' alternative conceptions. The educational software use can effectively contribute in both the above directions.

Among the various computer applications, simulations are of special importance in Physics teaching and learning. Simulations are open environments, created in the framework of scientific theories, where students are able to experiment with, make assumptions and derive conclusions in order to study the physical laws. They can be used as instructional tools with applications in Science teaching from primary [8, 9] to University level [10]. This is a field of convergence between the research in Science education and the educational use of computers, since their exploitation allows both the broadening of cognitive activities children may process, and the enhancement of teachers' instructional potentialities.

The present study follows the second last research direction. We have specified students' cognitive constraints originating from their alternative conceptions about velocity and acceleration in various experimental conditions. Then, we have tried to guide students to overcome their constraints by working with simulations through Interactive Physics [11].

Students' alternative conceptions about velocity and acceleration have been extensively studied and are considered not to be easily changeable with traditional instructional methods. Students often create analogies between velocity and acceleration. They consider that velocity describes only how fast an object moves, and acceleration describes only the increase of velocity [12-16]. They usually confuse the concepts of average and instantaneous velocity [17].

Moreover, students at all levels face major difficulties when using graphical or stroboscopic representations of motions. They usually think of the representation as a picture of the motion. Concerning the stroboscopic representations, they believe that the closer the traces are, the faster the object moves [18-20]. The same alternative conceptions are found during the use of educational software, among others connected with the use of information technologies. An example is the confusion between the concepts of velocity and acceleration in the case of two moving objects, and their connection with other physical concepts such as the object's position [13,17, 21, 22].

It has been found that simulations through Interactive Physics assisted students to overcome their cognitive constraints about the trajectory motion [23]. This study describes the effectiveness of simulations on helping students to remedy their conceptions about kinematical concepts. This is evaluated by analyzing the results of the pre- and post-tests data. We have identified most of the above alternative conceptions. Furthermore, there is evidence for improved students' performance by transforming their ideas after the use of simulations.

SIMULATIONS THROUGH INTERACTIVE PHYSICS

Interactive Physics is a two-dimensional virtual physics laboratory that simulates effectively the fundamentals of the Newtonian mechanics [24]. Simulations are based to numerical analysis methods (Euler or Kutta-Merson). The user may integrate a virtual experiment by drawing objects, giving them properties, introducing values to the physical parameters or changing the initial conditions. When running the simulation, the computer shows the evolution of the experiment on the screen. Data coming from the simulation can be displayed and recorded using virtual meters.

We have chosen Interactive Physics for two reasons. Firstly, because of its friendly and flexible user interface which is offered for the students' active engagement in Physics simulations. Secondly, because of its powerful environment which is suitable for the stroboscopic study of physical phenomena.

Stroboscopic representations may support instruction of kinematics, since they facilitate experimental studies, measurement or computation of the physical magnitudes (time, position, velocity, acceleration, etc.), and formulation of the physical laws. Interactive Physics is an alternative instructional tool, taking into account the inherent difficulties of the stroboscopes when used for experimental studies in the lab.

Figure 1 shows an Interactive Physics III screen shot that simulates an object uniformly accelerating down an incline. The various frames, giving the successive positions of the object, are also presented. During the post-test of the present study students used simulations of this type.

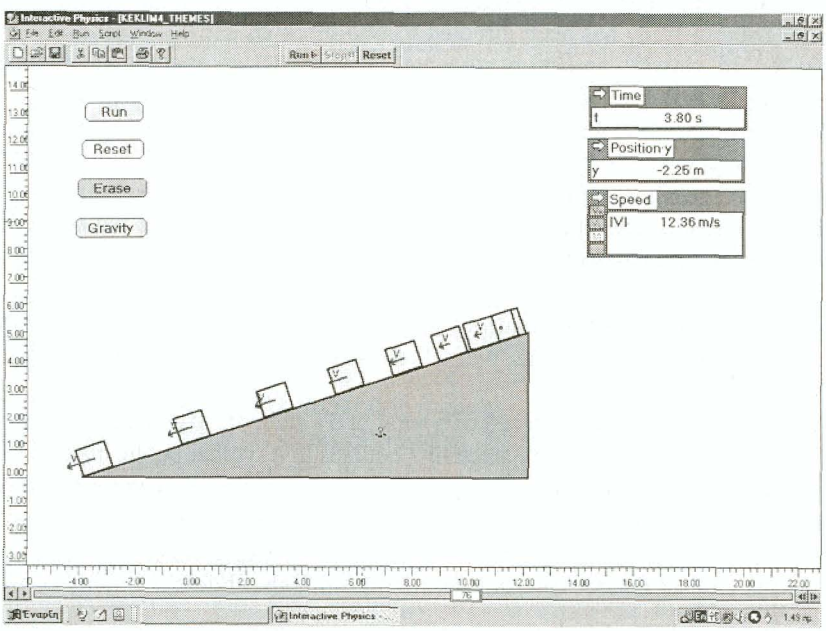

Figure 1. Interactive Physics III screen showing the simulation of an object accelerating uniformly down an incline

In order to facilitate usability, we have built a simple and friendly user interface. The students used simulations in player mode where software's tools were hidden. Furthermore, they had access to instructions such as RUN/STOP, RESET, ERASE (delete traces) and GRAVITY (change the value of the gravity constant) by clicking the relevant button.

METHOD

The basic kinematical concepts (instantaneous velocity and acceleration) and their instruction have received more research interest than any other since:

- Kinematics is the introductory topic in Mechanics, which is recognized as a "building block'' upon which other concepts are based [20]
- They have special educational value offered for the investigation of students' perceptions and cognitive difficulties
- It is easy to experiment with for the evaluation of innovative instructional environments.

According to our knowledge, this is the first study that uses Interactive Physics as a research tool in order to investigate and reform students' alternative conceptions. Furthermore, it is interesting to compare our results about students' ideas in kinematics with those of similar researches [13-17, 21]. The case of Greece also presents a peculiarity rooted in a special lingual constraint. The Greek word for velocity is "*tachi*tita" while for acceleration is "epi*tachi*nsi". So students in primary and secondary education are faced with an additional constraint originating in the above etymological reason.

The present study has been directed to two research axes.

1. To record, classify, and study students' ideas on basic concepts of kinematics, such as the instantaneous velocity and acceleration.
2. To study the contribution of computer simulations in students' conceptual understanding of the kinematical concepts and construction of mental models.

The corresponding hypotheses were:

1. The majority of the students have difficulties in understanding the concepts of velocity and acceleration, and applying them in effectively interpreting simple motions.
2. Students working with simulations will overcome their alternative conceptions and will be guided to the mental construction of the relevant scientific conceptions.

The research was administered to a total of 57 students attending the first year of Lyceum*. The students were attending courses in a typical public high school in the city of Ioannina, Greece and represented a wide range of achievement levels. Their average age was 15.6 years. All the children came from the middle social class. None of them had previous physics laboratory experience.

In the case of Greece, Physics instruction in high schools is mainly based on

* Lyceums are schools providing upper secondary education in Greece (3 grades in total).

traditional courses in the classroom while students' active engagement (experimentation in the Physics lab, use of computer simulations or spreadsheets) is rare. On the contrary, most of the students in the sample (75%) had a previous experience in the use of computers and of a general purpose software. Students with no computer experience had a short period of practice in order to be able to work with the proposed software.

PROCESS

The research was carried out six months after the instruction of kinematics at school. We used an open-ended questionnaire, developed by us for this study. No additional instruction about these topics was given before the study. The research was administered in two phases. In the pre-testing, students were asked to answer on the tasks-experiments and to give their predictions, estimations and rationales. We asked them to evaluate qualitatively the physical processes concerning the concepts of velocity (v) and acceleration (a) and justify their responses without using mathematical expressions.

The post-test phase took place fifteen days later. Initially, the students had worked with the simulations of the questionnaire's tasks developed through Interactive Physics. Then they were asked to respond to the same questions. Each student was working with the computer individually, using every simulated task as long as it was necessary for him to understand the phenomenon and the relationships between the physical concepts involved. Students used the software in player mode, having access only to the relevant buttons.

The experimental simulations-tasks used in our research are extensions of the Piagetian kinematical tasks [25]. They have been applied in similar versions for the study of students' alternative conceptions about velocity and acceleration using a demonstration apparatus [13, 14].

RESULTS

From a qualitative point of view, students' answers were similar before and after the use of computer simulations, but different concerning their frequencies. We have classified students' responses in the various tasks, in six categories:

i) effectual answers, where students gave correct answers based on justifications compatible with the relevant scientific models.
ii) confusion between the concepts of position (x) and velocity (v).
iii) confusion between the concepts of average (v_a) and instantaneous velocity (v_i).
iv) confusion between the concepts of velocity (v) and acceleration (a).
v) other answers, where students gave correct answers having no rationale or based on justifications that indicate various inefficiencies.
vi) inefficient answers, that were responses totally irrelevant to the subject of question or no answer at all.

Task 1. The study of two uniformly moving objects

Two similar objects move uniformly starting simultaneously as shown in Figure 2. The time intervals between successive positions are equal. a) Do the two objects ever have the same velocity? b) Estimate the acceleration of the two objects. c) Identify what type of motion each object does. Justify your answers.

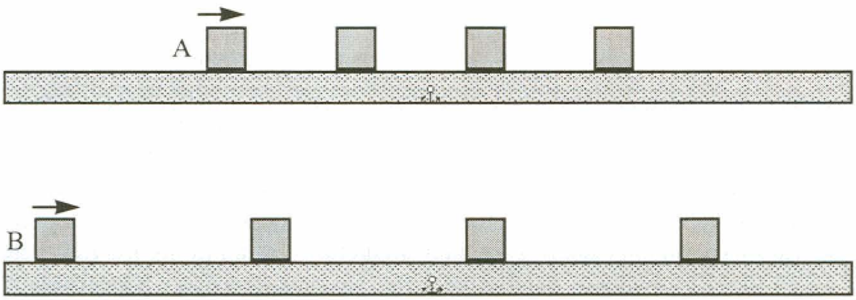

Figure 2. The study of two uniformly moving objects (task 1)

Table 1 shows the students' responses to the three questions of the task 1, concerning two uniformly moving objects, during pre- and post-tests. Approximately 4 out of 10 students in the sample had difficulties in applying effectively the concepts of velocity and acceleration. Students' misconceptions concerned confusion between position-velocity, velocity-acceleration, and average-instantaneous velocity. However, in the post-test phase, students gave scientifically correct answers at a higher percentage.

Table 1. Relative frequencies (%) of students' responses to task 1 (N=57)
(T=task, xi=question)

Answer	T1a pre	T1a post	T1b pre	T1b post	T1c pre	T1c post
Effectual	17.5	45.6	61.4	68.4	64.9	71.9
x and v confusion	24.6	19.3				
v_a and v_i confusion	12.3	10.5				
v and a confusion			19.3	15.8		
Other	10.5	14.1			21.1	15.8
Inefficient	35.1	10.5	19.3	15.8	14.0	12.3

In task 1a 17.5% of the students responded efficiently during pre-testing, while 45.6% of them gave correct answers after using simulations. Tasks 1b and 1c considered to be typical in the classroom routine and it seems that the students are familiar with them. In the pre -test phase more than 6 out of 10 students gave correct answer, while there is a small improvement during the post-test.

Examples of students' effectual answers are as following:

"The two objects have never the same velocity, because the second object has always greater constant velocity" (task 1a)

"Both objects' acceleration is zero, because their velocity is constant" (task 1b)

"Both objects move uniformly because they have a constant velocity" (task 1c).

The most frequent alternative conception recorded in task 1a is based on reasoning procedures indicating confusion between position and velocity of the objects. This confusion is found at a percentage of 24.6% (in pre-test) and 19.3% (in post-test). We classified in the above category responses such as:

"The velocity of the two objects is the same at the third snapshot, because they reach the same position".

In task 1a, we consider that students confused the concepts of average and instantaneous velocity, when they give justifications like

"The two objects have never the same velocity because they cover different distances at the same time".

In pre-test, students displayed the above alternative conception at a percentage 12.3%, while 10.5% of them gave the similar justifications during post-testing.

We identify nondiscrimination between velocity and acceleration (task 1b) in students' statements like

"The second object has greater acceleration, because it covers greater distances at the same time".

A considerable percentage of students in both phases of the research exhibited various inefficiencies giving correct answers with no rationale or with justifications like

"The two objects have never the same velocity because their motions are totally different" (task 1a).

Students exhibited inefficient approach in task 1 at a percentage of 24.6% (in pre-test) and 19.3% (in post-test). We classified in this category responses such as

"They always have the same velocity because both objects move uniformly" (task 1a)

"The two objects make a constant motion" (task 1c).

In task 1 we found common misconceptions such as confusion between position-velocity and average-instantaneous velocity at significant percentages. We also recorded higher scores in students' responses after using simulations. Furthermore, we observe students' systematic shift from totally inefficient answers to the various conceptual difficulties and, finally, to scientifically correct answers. This is an indication about the instructional value of simulations, since it strongly confirms our hypothesis that working with simulations allows students to overcome various cognitive constraints and leads them to conceptual understanding of the kinematical concepts in uniform motion.

Task 2. The study of a uniformly moving and a uniformly decelerating object

Two similar objects A and B start simultaneously with different initial velocity and are moving as shown in Figure 3. The time intervals between successive positions are equal. a) Do the two objects ever have the same velocity? b) Which one of the objects has greater initial velocity? c) What type of motion each object does? Justify your answers.

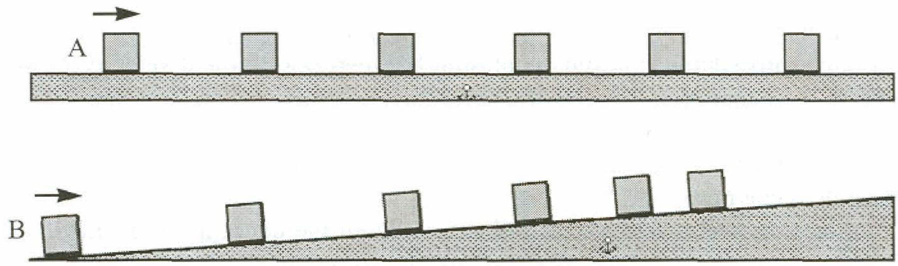

Figure 3. The study of a uniformly moving and a uniformly decelerating object (task 2)

This task investigates students' ideas about velocity and acceleration by asking them to compare the kinematical characteristics of a uniformly moving object and a uniformly decelerating object. Students' answers in the second task are classified in Table 2.

Table 2. Relative frequencies (%) of students' responses to task 2 (N=57) (T=task, xi=question)

Answer	T2a pre	T2a post	T2b pre	T2b post	T2c pre	T2c post
Effectual	22.8	45.6	28.1	47.4	63.2	84.2
x and v confusion	28.1	19.3				
v_a and v_i confusion			29.8	10.5		
Other			29.8	19.3	28.1	5.3
Inefficient	49.1	35.1	12.3	22.8	8.8	10.5

In this task we have also identified common misconceptions concerned the confusion between position-velocity, and average-instantaneous velocity. There is a remarkable improvement in students' responses in the post-test, where their scores increased at 45.6% (task 2a) and 47.4% (task 2b).

Students' effectual answers were based on arguments like:

"Yes, because object B is uniformly decelerated with greater initial velocity and at some an instant its velocity will be equal to the velocity of the object A" (task 2a)

"Object B has a greater initial velocity, because it covers a greater distance in the time interval between the first and the second track" (task 2b).

The students in the sample identified precisely the type of objects' motion (task 2c) in both phases of the research. They gave efficient responses during the pre-test at a percentage of 63.2%. After working with simulations this score was significantly improved at 84.2%. This task is a routine subject in conventional physics instruction and it seems that most of the students are familiarized with it.

An interesting alternative conception recorded in task 2a was the confusion between position and velocity. Students, expressing this idea, make their estimations about objects' instantaneous velocity using arguments based on their position, such as

"The two objects have the same velocity at the third and fourth track, because they reach at the same position"

"The two objects never have the same velocity because object A goes always first".

Answers showing confusion between average and instantaneous velocity (task 2b) were like:

"Object B has a greater initial velocity, because it covers a greater distance than object A".

The students are able to at a percentage of 47.4% understand and justify correctly that the object moving up the incline was started with greater initial velocity. It seems that working with computer simulations children can overcome their confusion between the concepts of average and instant velocities. During the pre-test, 29.8% of the children did confused the concepts of average and instant velocities, while only 10.5% hold the above difficulty during the post-test.

In the category of other answers are included students' correct responses in tasks 2b and 2c with no rationale at all.

Students' inefficient answers were like:

"The two objects never have the same velocity because their motion is different and their velocity will be also different" (task 2a)

"Object B has a greater initial velocity, since it moves on an incline" (task 2b).

The students in the sample identified precisely the type of objects' motion (task 2c) in both phases of the research. They gave efficient responses during the pre-test at a percentage of 63.2%. After working with simulations, this score was significantly improved at 84.2%. This task is a routine subject in conventional instruction of Physics and it seems that most of the students are familiarized with it.

Task 3. The study of two uniformly accelerated objects

Two similar objects A and B start simultaneously accelerating uniformly down an incline as shown in Figure 4. The two inclined planes are geometrically similar. The time intervals between successive positions are equal. a) Do the two objects ever have the same velocity? b) Do the two objects have the same acceleration? c) Which object reaches the ground with the greater velocity? Justify your answers.

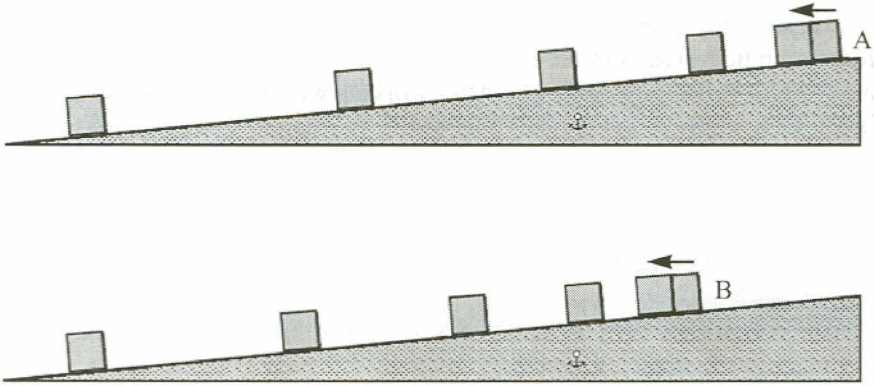

Figure 4. The study of two uniformly accelerated objects (Task 3)

Task 3 investigates students' ideas about velocity and acceleration using two similar uniformly accelerating objects. Table 3 classifies students' responses during pre and post - tests. It is evident from our results that students exhibited higher scores after using simulations.

Table 3. Relative frequencies (%) of students' responses to task 3 (N=57) (T=task, xi=question)

Answer	T3a pre	T3a post	T3b pre	T3b post	T3c pre	T3c post
Effectual	19.3	29.8	21.1	33.3	28.1	38.6
x and v confusion	21.4	14.0			17.5	3.5
v_a and v_i confusion					14.0	14.0
v and a confusion			28.1	19.3		
Other	36.8	28.1				
Inefficient	22.8	28.1	50.9	47.4	40.4	43.9

Students' correct answers were based on arguments indicating conceptual understanding of the kinematical concepts like:

"The two objects never have the same velocity, because they always cover different distances at the same time interval" (task 3a)

"Object A has a greater acceleration, because it covers a greater distance at the same time, while both objects were started from rest" (task 3b)

"Object A reaches the ground with the greater velocity, because the distance between the last two tracks is greater than object's B" (task 3c)

"Object A reaches the ground with the greater velocity, because it is accelerating with a greater acceleration than object B" (task 3c).

Answers showing confusion between position and velocity are like:

"The two objects have the same velocity at the last track of the path, because the are side by side" (task 3a)

"The two objects have the same velocity, because they reach the ground simultaneously" (task 3c).

Answers showing confusion between velocity and acceleration are like

"The two objects have different acceleration, because their velocities are different" (task 3b).

It seems that the above students were unable to make the necessary distinction between the concepts of velocity and change of velocity (acceleration).

More than 3 out of 10 students (36.8% during pre- test and 28.1% during post-test) exhibited various inefficiencies giving correct answers with no rationale or with justifications like

"The two objects have never the same velocity because their motions are totally different" (task 3a)

In task 3, a considerable percentage of students gave inefficient answers before and after the use of simulations. Examples of their justifications were like:

"The two objects have the same instant velocity at the starting point" (task 3a)

"The two objects have the same acceleration, because they reach the ground simultaneously" (task 3b).

"Object A reaches the ground with the greater velocity, because it starts accelerating from a higher point" (task 3c).

After the use of simulations, students in the sample exhibited a remarkable progress concerning the effectual answers. There is an explicit shift of the students from their inefficient approaches and alternative conceptions (position-velocity confusion, velocity-acceleration confusion) to meaningful understanding of the concepts.

Task 4. The study of a ball bouncing on the ground

A basketball falls freely from a specific height, reaches the ground and bounces up reaching its initial height. Figure 5 shows the successive positions of the ball after bouncing. The time intervals between successive positions are equal. a) Find the positions having minimum and maximum velocity. b) Estimate the velocity and the acceleration when the ball reaches its maximum height. c) Estimate the acceleration of the ball in its successive positions. Justify your answers.

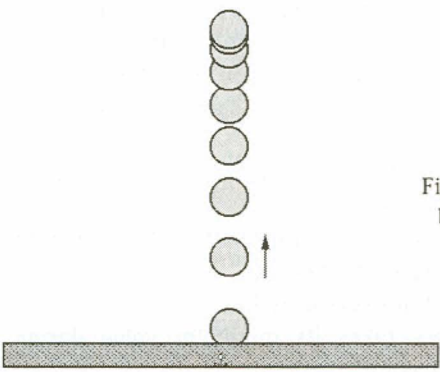

Figure 5. The study of a ball bouncing on the ground (task 4)

This task investigates students' ideas about velocity and acceleration of a ball bouncing up to its initial height. The kinematical characteristics are common with those of a ball freely falling in the gravitational field. Table 4 classifies students' responses during pre and post - tests. Although the free fall is a typical paradigm in kinematics instruction, students in the sample faced serious difficulties in interpreting qualitatively the above task.

Table 4. Relative frequencies (%) of students' responses to task 4 (N=57) (T=task, xi=question)

Answer	T4a pre	T4a post	T4b pre	T4b post	T4c pre	T4c post
Effectual	19.3	33.3	14.0	21.1	12.3	22.8
v and a confusion			49.1	57.9	40.4	45.6
Other	59.6	57.9			10.5	1.8
Inefficient	21.1	8.8	36.8	21.1	36.8	29.8

Examples of students' effectual responses to the above task are

"The ball's velocity is minimum (zero) at the highest point and maximum at the bouncing point" (task 4a)

"At the highest point, the ball's velocity equals zero and its acceleration equals the gravity constant" (task 4b)

"The ball's acceleration is constant, and equals the gravity constant" (task 4c).

In task 4a, during the pre-test, 59.6% of the students gave correct answer with no justification or incorrect justifications like

"The ball's velocity takes its maximum value during the bounce and is minimum at the upper point, because there is no force to support moving higher". This approach is resisted at a percentage of 57.9% during the post-test.

In task 4c, during the pre-test, 10.5% of the sample gave correct answers with no justification, while only one student exhibited this approach after the use of simulations.

The most frequent misconception identified seems to be the confusion between the concepts of velocity and acceleration. Students exhibited this confusion at a higher percentage after using computer simulations due, mainly, to their shift from totally inefficient responses. It seems that the dynamic environment of simulations can not help students to overcome this constraint effectively.

Examples of students' expressions showing confusion between velocity and acceleration are like

"At the highest point, the ball's acceleration equals zero because its velocity is zero too" (task 4b)

" The ball's acceleration increases continuously when the ball falls freely and decreases when it bounces up" (task 4c).

Students' inefficient answers were like

"The ball's velocity takes its minimum value during the bounce and is maximum at the upper point" (task 4a)

"The ball's velocity is minimum during its free fall and maximum during its upwards motion" (task 4a)

"Both the velocity and acceleration are equal to their initial values, since the object reaches again its initial position" (task 4b)

"The ball's acceleration is proportional to its position" (task 4c).

There is a small improvement in students' answers during post-test, in all the questions of the fourth task. This is an indication that the simulated experiment allows the students to understand the kinematical characteristics of the task, which is a special case of a trajectory motion. The investigation of this task is a subject where students encounter difficulties similar to the free fall's study. The concepts of the velocity and acceleration, at the upper point of a vertically thrown object, are described as a topic of special difficulty [26]. It seems that even the use of the simulation requires students' deeper physics background, in order to achieve meaningful understanding of concepts like acceleration, which is the rate of change of velocity, or in other words the rate of change of the rate of change of position.

DISCUSSION

This article presents the effect of computer simulations through Interactive Physics on students' alternative conceptions about velocity and acceleration. Our results confirm in general our hypothesis that computer simulations allow students to overcome cognitive constraints coming from their alternative conceptions.

We have detected various misconceptions found in related studies [13, 14, 17, 21]. Students' confusion between velocity and position, instantaneous and average velocity, and velocity and acceleration seems to play important role in their believes about kinematics. Most of the students' inefficiencies are due to reasoning procedures focused on the contextual features of the kinematical processes of the tasks.

Figure 6 presents students' effectual answers to the tasks of the research during the pre and post-tests. It seems that students working with simulations may confront their cognitive difficulties up to a certain point. However it is obvious, that the progress of the students is different for the various tasks of the research. We have found a significant improvement for tasks 1 and 2, which concerned uniformly moving objects. For the third and fourth tasks where the moving objects are accelerating, the results are satisfactory at a lower degree since there is improvement for quite a few students. The velocity and acceleration comparison of non-uniformly moving objects (tasks 3 and 4) incorporates special difficulties, since the simultaneous discrimination between position change and velocity change on time unit requires higher order reasoning.

A second important topic in our study is the way we have used simulations. In order to evaluate the effectiveness of simulations in students' conceptual understanding, we ask them to work with simulations all alone. Our role was restricted to observe their active engagement and give technical support, without intervening even in cases where our help could be determinant for the students' progress.

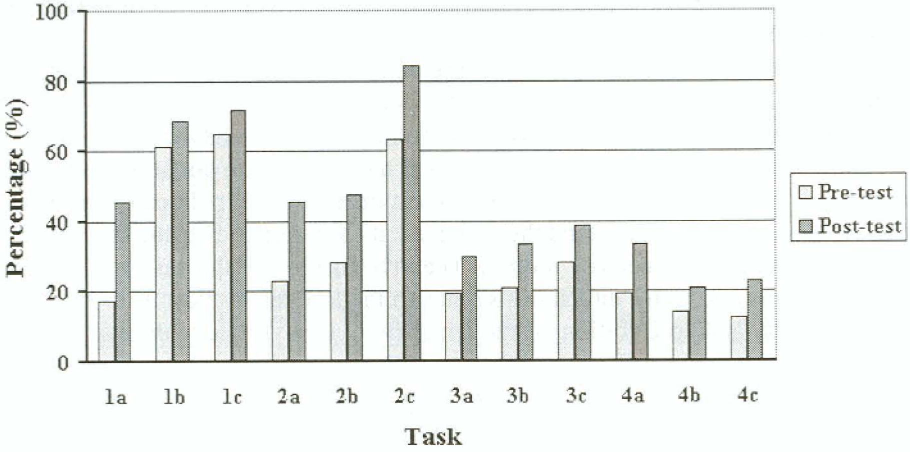

Figure 6. Students' effectual answers during pre and post - tests

However our results allow us to orient any teaching intervention in the correct way, since they detect the difficulties that students can not overcome using simulations individually. Such a point of view is absolutely compatible with the current research directions in Science education, giving emphasis in the systematic study of student-teacher interaction that aims at the attainment of well assigned cognitive transformations [27].

What also observed during this study, was the enthusiasm and convenience with which students were engaged in simulations. This observation together with the exploitation of the stroboscopic representation, provided by the simulations, gives us an indication for the value of software packages of this type in Physics instruction.

Traditional instruction is insufficient to help students confront their alternative conceptions. Teachers should give to their students a large variety of special instructional situations to interact with them, in order to investigate, predict, and, finally, understand the physical laws. Computer simulations offer the opportunity to the students

- to consider their own ideas about kinematical concepts
- to interact with them executing virtual experiments
- to modify their ideas promoting conceptual change.

The improvement of simulations and their effective use in Physics education are open research subjects. Simulations have been extensively used as a virtual physics laboratory for modeling and presenting phenomena or processes. But, in a constructivist perspective of physics instruction, they could offer an expressive environment where students can demonstrate their ideas or mental models, make predictions, record experimental data, derive the physical laws, solve problems, and, finally, achieve functional understanding of Physics. Our present research interests are focused towards the above direction.

Author Note

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ΣΥΝΟΨΗ

Στην εργασία αυτή παρουσιάζονται τα αποτελέσματα της χρήσης προσομοιώσεων σχετικά με την άρση των παρανοήσεων μαθητών Α' τάξης του Λυκείου για τις έννοιες της ταχύτητας και της επιτάχυνσης. Αρχικά προσδιορίζουμε και διερευνούμε τις αντιλήψεις και τις γνωστικές δυσκολίες που εμφανίζουν οι μαθητές στα τέσσερα έργα της έρευνας σχετικά με τις κινηματικές έννοιες. Διαπιστώνουμε ότι οι μαθητές εμφανίζονται να συγχέουν τις έννοιες ταχύτητας-θέσης, ταχύτητας-επιτάχυνσης και στιγμιαίας-μέσης ταχύτητας. Στη συνέχεια αξιολογούμε τη συμβολή της χρήσης προσομοιώσεων, που δημιουργήθηκαν μέσω του λογισμικού Interactive Physics, στην κατανόηση απλών κινηματικών φαινομένων και στη δημιουργία νοητικών αναπαραστάσεων. Η επεξεργασία των αποτελεσμάτων μας δείχνει ότι οι προσομοιώσεις βοηθούν τους μαθητές να ξεπεράσουν γνωστικές δυσκολίες, που οφείλονται στις παρανοήσεις τους σχετικά με τις έννοιες της στιγμιαίας ταχύτητας και επιτάχυνσης.