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THE EFFECTS OF THE COMPUTER SIMULATIONS ON STUDENTS' LEARNING IN PHYSICS EDUCATION

Dr. Tolga GOK
University of Dokuz Eylul
Torbali Technical School of Higher Education
35860, Izmir, TURKEY

ABSTRACT

Broad acceptance of web-based software as a teaching-learning medium for processing information has opened new vistas in education by taking full advantage of learners' basic senses of learning such as visualizing 3D objects and fundamental concepts with applets. Applets provide animated, interactive and game-like environments in which students learn through exploration. Most of the applets are available on-line cover high school and college science courses. This study focuses on the technical and pedagogical benefits of more advanced-topics-related applets used in physics course. These applets emphasize the connection between real-life phenomena and the underlying science. Also, the effects of physics concept learning with computer simulations and traditional physics learning without computer simulations on students' achievement and attitude were compared. The study was performed on two groups (total 93 students) during one semester at a public university in the west of the Turkey. When the results obtained from the study were evaluated statistically, it was found that there was a significant difference in conceptual test between groups' scores in favor of the treatment group. Also, it could be concluded that the courses with computer based-activities have a positive effect on students' attitude. According to the results of this study, the present study suggests that carefully developed and tested educational applets in conjunction with real-equipments can be engaging and effective in students' understanding of the physics.

Keywords: Applets, computer simulation, educational technology, learning environment, physics education.

INTRODUCTION

The use of educational technologies, such as computer animations and interactive simulations, in science and engineering courses has increased dramatically in the last decade. The popularity is partly because of the fact that simulations are easy to integrate into a curriculum. Most of the textbooks used in the college courses now include various simulations as DVDs or a URL to websites (Wieman & Perkins, 2006). Available simulations are stated as an interactive multimedia which is a combination of multimedia and interaction. The media are composed of text, image and/or movie. The interaction is composed on trigger and action. Java applets written by a powerful programming language from SUN Microsystems are simple solutions for excellent educational multimedia because of image, sound, and interaction powers. Java applets can easily be included in a html document with other multimedia elements such as images, graphs, diagrams, tables, videos, and audios allowing an easy configuration of dynamic multimedia learning materials (Wieman et al*.,* 2008a).

A number of control buttons below the applet itself allow students to start, stop, and step the animations, and the mouse can be used to read scaled coordinates and to drag and drop objects around the frame. Each applet is designed to focus on a single physical principle or concept, excluding unnecessary detail; this keeps applets small and easily downloadable over the internet on a range of connection speeds.

Also, as a result of their simplicity, applets do not require lecturers to adhere to a particular pedagogical approach, though the creators point out that applets are most effective when used in collaborative learning or tutorial-type settings (Krusberg, 2007).

Applets are effective learning tools; however, to enrich the teaching-learning environment they must still be a part of instructional design (an experienced instructor and a well-designed curriculum). Educational applets should follow the same basic strategies with in effective teaching. These are to: a) define specific fundamental principles; b) encourage students to use sense-making and reasoning in words and diagrams; c) use students' before knowledge to build new concepts; d) make a connection to real-life experiences; e)increase collaboration in activities; f) be careful not to limit students' exploration; g) monitor students' understanding (Finkelstein et al., 2006).

An applet assists when instructor introduces a new topic, builds a concept, tries to reinforce ideas and provide final review and reflection (Wieman & Perkins, 2005). Also it creates a common visualization between students and instructors which facilitates the communication and teaching. Group activities are even more substantial for students in terms of working in pairs and manipulating applets themselves. In engineering and science courses, applets are widely used in various educational settings including lecture, in-class activity, small group activities, homework, and laboratory (Perkins et al., 2006).

The limitation of using pictures, words, and gestures in classical physical lecture makes harder to convey a fundamental concept to students or share the same visual models. Applet serves as versatile visual aid increasing the communication and allowing for interactive engagement through lecture demonstrations and concept test (Mazur, 1997). Also traditional assessment methods such as in-class quizzes can be replaced or supplemented with the simple applet-based multiple-choice on-line tests with a variety of questions (Kamthan, 1999). Besides, having access of students to internet encourages asynchronous distance learning and they can study the course material from home in their own time. Applet-based homework questions increases exploration motives of students before the lecture.

Applets offer the same benefits as the demonstrations using real equipment also following advantages. Students can:

- use where the real equipment is either not available or impractical to set up;
- change variables easily in response to students' questions that would be difficult or impossible to change with real apparatus;
- show the invisible connections explicitly with multiple representations;
- run the applets on their own computer at home to go over or extend the experiments to clarify and strengthen their understanding (Finkelstein et al., 2005).

While many researchers (Azar & Şengüleç, 2011; Christian & Belloni, 2001; Bayrak, 2008; Bozkurt & Ilik, 2010; Krusberg, 2007; Viadore, 2007) find it appealing to use simulations in their classroom, little research has been done to determine if simulations improve a learner's understanding of or enthusiasm for science and how simulations can be designed and used most effectively. The main aim of this study was to compare the effect of physics concept learning with computer simulations and traditional physics learning without computer simulations on college students' physics achievement. In this study, the author examines the following questions:

- Is there any statistically significant difference between physics concept learning with computer simulations and traditional physics learning without computer simulations groups' conceptual understanding?
- Do students find computer simulations as a positive learning experience?

METHOD

The study was conducted on college physics course (covering electricity and magnetism) during the spring of 2010 (S10). The subjects in this study consisted of 93 students attending a public university in the west of the Turkey. The research method was a quasi-experimental design in which an instructor who was assigned to teach two lecture sections of the same course. The quasi-experimental design consists of two groups that one group is subjected to a treatment and the other is subjected to a control group (Fraenkel & Wallen, 1996). In the study, there were two identical classes, namely, traditional physics learning without computer simulations (TPL) and physics concept learning with computer simulations (PCL). 47 students in the TPL class were the control group. 46 students in the PCL class were the experimental group.

Before the intervention, all participating students took a pretest. The pretest scores were used to test the equivalence of the two groups and for analysis of students' performance. The posttest scores were used as the dependent variable. Conceptual Survey in Electricity and Magnetism (CSEM) was used to provide data for quantitative analyses and to evaluate students' physics performance. Also, an evaluation questionnaire toward computer simulations was used to provide data for quantitative analyses and to access students' opinions on their learning experiences with computer simulations.

Students in the PCL and the TPL groups were taught the same concepts during one semester. Both groups were given the same time period. This course for non-science students has four credit hours. Students in the PCL group attended to lectures three hours and then each student studied the assigned applets in the computer laboratory class one hour per week. Students in the TPL group attended to lectures four hours in a week. All students in the PCL group completed a worksheet while interacting with the assigned computer simulations. The worksheet is aiming at encouraging students to reflect on the simulated phenomena and to present related conceptual reasoning to explain the phenomena. Specifically, students are required to:

- identify the physics principle(s) or concept(s) to explain the physics phenomena,
- articulate the rationale to use a particular principle or concept to explain the physics phenomena, and
- describe how principles or concepts are applied to explain the physics phenomena.

The simulations were selected from the physics education technology (PhET) made by the physics education research group at University of Colorado at Boulder. The simulations are designed to be highly interactive, engaging, and open learning environments that provide animated feedback to the user. The simulations are physically accurate, and provide highly visual, dynamic representations of physics principles. Simultaneously, the simulations seek to build explicit bridges between students' everyday understanding of the world and the underlying physical principles, often by making the physical models (such as current flow or electric field lines) explicit (Finkelstein et al., 2006). Concepts in electricity and magnetism (E&M) were chosen as the topic for this study because of their abstracts nature. Total eleven research-based applets, shown in Table: 1, were used in this study.

Students engaged in a series of exercises including: DC-circuits (examining resistors in series and parallel, building a simple circuit and then predicting, observing, and reconciling its behavior as various elements (resistor and bulbs) were added or rearranged, and finally developing methods to measure resistance in multiple ways in these circuits); Electrostatics (measuring the static charge); Magnetics (introducing Faraday's Law, magnetic force balance, and metal detector activity). Some applications used in the computer laboratory class were given as follows.

Table 1
The list of the conducted applets

The Number of the Experiments	The Chapter of the Experiments	The Name of the Experiments
1	Electricity	Balloons and Static Electricity
2		Charges and Fields
3		Ohm's Law
4		Resistance in a Wire
5	Circuits	Circuit Construction Kit (DC only)
6		Circuit Construction Kit (AC+DC)
7		Signal Circuit
8	Magnets	Faraday's Electromagnetic Lab
9		Faraday's Law
10		Magnets and Electromagnets
11		Magnet and Compass

An example of applets used for electrostatic chapter, shown in Figure 1a, traditional balloon demo is presented in which students can observe the electric charges.

Although the simulation is simple, it is effective for animating the Coulomb attraction between oppositely charged objects and the movement of negative charges (electrons) as they are transferred from the sweater to the balloon when rubbed together. Polarization is also represented as the negative charges in the wall shift away from their positive ion cores (nuclei) as a charged balloon approaches (Perkins et al*.,* 2006).

Another applet application used in laboratory can be Circuit Construction Kit (CCK) applet, shown in Figure 1b. It offers a learning environment similar to the real-life laboratory. Students connect light bulbs, switches, batteries, resistors, and wires to create arbitrarily complex DC circuits. Realistic looking voltmeters and ammeters are used to measure voltage differences and currents.

Also this, the CCK applet introduces an animation of the electrons flowing through the circuit elements and the ability to continuously adjust the resistance of any component or the voltage of the battery. Students can close/open the switch and change the resistance of the resistor. So, students observe the change in the motion of the electrons, the brightness of the bulbs, and monitor the voltage difference. This applet orients the students to examine the relationship between the reason and the effect (Wieman et al*.,* 2008b).

As an example of applets used for magnetism chapter, magnets and electromagnets applet (Figure: 1c) is presented in which students can predict the direction of the magnetic field for different locations around a bar magnet and electromagnets; identify the characteristics of electromagnets that are variable and what effect each variable has on the magnetic field's strength and direction, and; relate magnetic field strength to distance quantitatively and qualitatively (PhET, 2011).

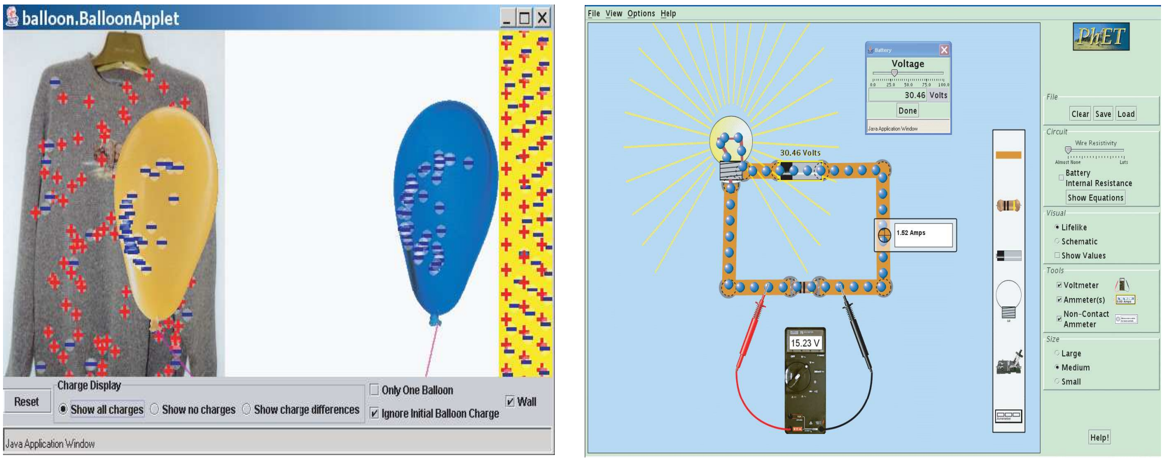
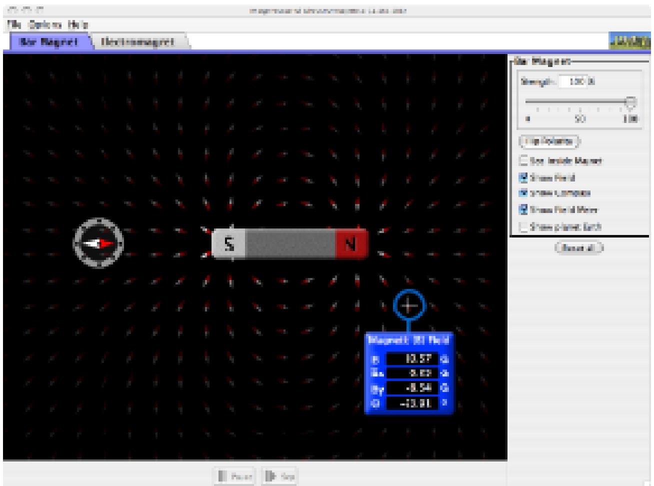


Figure 1
a. Balloons and Static Electricity; b. Circuit Construction Kit "CCK" (DC Only)



c. Magnets and Electromagnets
Note: Applets developed by the physics education research group at University of Colorado at Boulder (http://phet.colorado.edu/index.php) were used in this study.

The Data Collection Tools

The data of the study was collected in three different ways:

- conceptual test (Conceptual Survey of Electricity and Magnetism "CSEM") scores,
- evaluation questionnaire towards computer simulations, and
- instructor' observation in the computer laboratory class.

Conceptual Survey in Electricity and Magnetism (CSEM)

Conceptual Survey of Electricity and Magnetism (CSEM) consists of thirty-two question, this multiple-choice conceptual test designed to assess student's knowledge of topics in electricity and magnetism (Maloney et al., 2001). Generally, student's scores on CSEM are analyzed by calculating the normalized gain (Hake, 1998). He defines three ranges of g: low (0-0.3), medium (0.3-0.7), and high (0.7-1.0).

The Hake gain is a normalized gain defined as;

$$g = \frac{\text{Actual gain}}{\text{Max. possible gain}} = \frac{\text{Posttest} - \text{Pretest}}{\text{Max. score} - \text{Pretest}}$$

"g" measures the percentage improvement of the posttest score relative to the pretest score compared with the maximum amount of improvement that could have achieved. This, in turn, is assumed to be the improvement because of the learning that took place between the pre-and-post tests. This conceptual test was given on the first day of class as a pretest and on the final day of class as a posttest to groups.

Evaluation Questionnaire for Computer Simulations (EQCS)

The purpose of the evaluation questionnaire is to access students' opinions of the usefulness of computer simulation learning experiences, the attitudes toward computer simulations, the impact on content knowledge, and the influences on cognitive skills (Chou, 1998).

After interacting with computer simulations, students in the PCL group were asked to complete this questionnaire to provide insight into their learning experiences. It was made clear, at the beginning of the evaluation questionnaire, that in all the statements, "computer simulation" refers to all the materials related to the learning with computer simulation activity, including the computer simulations.

Twenty items of the Likert scale questions are positively phrased and the rest are negatively phrased. The validity and reliability of the EQCS was done by Chou (1998). Among the thirty Likert scale questions, six items concern students' perceptions of the use of computer simulations after completing this study.

The eleven items in the second category were to access students' attitude toward the learning framework under examination in this study.

The third category focused on the influences of the learning framework on the information a student has at his or her disposal in the area of physics. There were seven items in this category. Finally, the five items in the last category were associated with cognitive skills such as students' ability to think and reason.

The Data Analysis

The data obtained by administrating the CSEM and EQCS to students was analyzed by using SPSS 16.0 program. For analysis of data, the data obtained from the EQCS scored by 1, 2, 3, 4, and 5 respectively for the choice of "strongly disagree", "disagree", "neutral", "agree", "strongly agree" and for all items. The minimum score of this five-point Likert scale is 30 and the maximum score is 150.

Then, to compare the effects of two different teaching methods, arithmetic mean, standard deviation, independent t-test, and gain factor statistical techniques were used. All parametric tests were conducted at a probability level of 0.05 (95% confidence).

RESULTS AND DISCUSSION

To determine whether learning outcomes are as good for PCL as for TPL the author examined the pretest scores and posttest scores. The author collected data on pre/post conceptual test scores, and attitude scores. The CSEM was administered to all students in the course at the beginning and end of the semester.

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The CSEM pretest provides a measure of previous physics understanding from formal or informal learning. Improvement between pretest and posttest provides a measure of conceptual learning.

The results of the CSEM pre-and-post test scores, and normalized gain scores also known as Hake factor for groups are given in Table: 2.

Table 2
The results of CSEM for groups

Semester	PCL			TPL		
	Pretest	Posttest	Gain *"g"*	Pretest	Posttest	Gain *"g"*
S10	40.5	62.7	0.37	40.8	54.3	0.22

It could be concluded from Table 2 the conceptual test score of the PCL group was higher than the TPL group' conceptual test scores. When the gain factors of the groups were evaluated, it could be said that the PCL' gain factor was medium (g=0.37) and the TPL' gain factor was low (g=0.22). The independent t-test results of the groups were given in Table: 3.

Table 3
The results of the comparison of pretest and posttest scores of the groups

CSEM	Group	*N*	*M*	*SD*	*df*	*t*	*p**
Pretest	PCL	46	40.5	5.26	91	0.27	0.78
	TPL	47	40.8	5.20			
Posttest	PCL	46	62.7	7.67	91	5.92	0.00
	TPL	47	54.1	6.09			

Note: *statistically significance defined as p<0.05; *M*: Mean; *SD*: Standard Deviation; *df*: Degree of Freedom; *p*: significance value; t_{table}=1.65.

It could be concluded from Table 3 that independent t-test was used to examine whether the difference in physics achievement according to the pretest and posttest scores of the PCL group and the TPL group was significant. According to the independent *t*-test results, it was found that there was a significant difference between groups' posttest scores of the CSEM (t=5.92, p<0.05) in favor of the PCL group.

Finally, students in the PCL group were asked to complete an evaluation questionnaire at the end of the last simulation session to provide insight into their learning experience. The results of the EQCS are given in the below.

The Likert scale questions were grouped into four (usefulness, influences on students' attitudes, influences on content knowledge, and influences on cognitive skills) categories. The first six questions focused on students' perceptions of the use of computer simulations as a learning tool after finishing this study.

It could be concluded from Table: 4 students strongly disagreed that they had difficulty using computer (M=1.02) and agreed that computer simulation is an appropriate technique to learn physics concepts (M=4.76). Students also agreed that computer simulation is a valuable tool (M=4.31) and that it should be used more often in physics learning and instruction (M=4.59), as well as that a course using a computer would be more interesting (M=4.28). They were less sure that they can learn the subject matter more easily if there were computer terminals in the classroom (M=3.52).

Table 4
The results of the EQCL' usefulness

Items	M	SD
The computer simulation is an appropriate technique to learn about concepts in physics	4.76	0.65
The computer simulation is a valuable tool	4.31	0.61
Computer simulations should be used more often in physics learning and instruction	4.59	0.87
A course that uses a computer in some of its teaching would be more interesting than a course taught without using a computer	4.28	0.85
If there were computer terminals in my classroom, I might be able to learn the subject matter more easily	3.52	1.01
I have difficulty using the computer as a learning tool because computers are too complicated	1.02	0.59

Note: M: Mean; SD: Standard Deviation

The eleven questions in the second category were used to access students' attitude toward the learning framework under examination in this study. It could be seen from the following Table 5 that students were more inclined to agree that with the effort they put into it, they were satisfied with what they learned while learning with the computer simulation (M=4.19). On the other hand, students disagreed that they felt frustrated by learning with computer simulations and that learning with computer simulations is just another step toward depersonalized instruction (M=1.73). Students also disagreed that learning with the computer simulation made them feel quite tense (M =1.79) or is inflexible (M=2.04). Students were more inclined to the neutral attitude that taking a course with the requirement to learn by using computer simulation would be too dehumanizing (M=2.46) and that the computer simulation made the learning more mechanical than traditional instruction (M=2.15).

Table 5
The results of the EQCL' influences on students' attitudes

Items	M	SD
I prefer learning with computer simulation than other learning procedures	4.41	0.99
While learning with the computer simulation, I felt challenged to do my best work	4.17	0.91
As a result of having studied some material with the computer simulation, I am interested in trying to find out more about the subject matter	4.23	0.87
I felt as if I had a private tutor while learning with computer simulation	3.21	1.01
With the effort I put into it, I was satisfied with what I learned while learning with the computer simulation	4.19	0.79
Taking a course with the requirement to learn by using computer simulation would be too dehumanizing	2.46	0.95
The computer simulation made the learning more mechanical than traditional instruction	2.15	0.85
The situation of having to learn with the computer simulation made me feel quite tense, comparing to the traditional way of learning physics	1.79	0.87
I felt frustrated by learning with the computer simulation	1.77	0.84
Learning with the computer simulation is inflexible	2.04	1.07
I am not in favor of learning with computer simulation because it is just another step toward depersonalized instruction	1.73	0.91

The third category concerns the influences of the computer simulation learning framework on the amount of information a student has at his/her disposal in the area of physics. There are seven items in this category. It could be concluded from Table 6 that students agreed that learning with the computer simulation improved their understandings of how theories can explain physical observation (M=4.45) and that it improved their understanding of the basic principles of physics (M=4.79). They were sure that learning with the computer simulation increased their factual knowledge of physics (M=4.38) or that it increased their interest in the theoretical and conceptual structure of physics (M=4.51). Students were also sure if learning with the computer simulation is superior to traditional way of learning (M=4.66). Students were more inclined to neutral about the statement that they just tried to get through the material rather than trying to learn (M=2.61). They disagreed that too much material was presented (M=2.22).

Table 6
The results of the EQCL' influences on content knowledge

Items	M	SD
Learning with the computer simulation improved my understanding of the basic principles of physics	4.79	0.87
Learning with the computer simulation increased my factual knowledge of physics	4.38	0.91
Learning with the computer simulation improved my understandings of how theories can explain physical observation	4.45	0.79
Learning with computer simulation increased my interest in the theoretical and conceptual structure of physics	4.51	0.90
In view of the amount I learned, I would say learning with the computer simulation is superior to traditional way of learning	4.66	0.91
I found myself just trying to get through the material rather than trying to learn	2.61	0.99
In view of the time allowed for learning, I felt too much material was presented	2.22	0.78

Finally, the five items in the last category are associated with cognitive skills such as students' ability to think and reason. It could be concluded from Table 7 that students agreed that the computer simulation improved their ability to think logically (M=4.37), to learn independently (M=4.28), and to solve new problems in physics by using basic principles and concepts (M=3.95). They were sure that the computer simulation improved their ability to think in abstract terms (M=4.25) or to use new approaches, or ideas when called upon to solve a problem (M=4.34).

Table 7
The results of the EQCL' influences on cognitive skills

Items	M	SD
The computer simulation improved my ability to think in abstract terms	4.25	0.83
The computer simulation improved my ability to think logically	4.37	0.92
The computer simulation improved my ability to learn independently	4.28	0.85
Learning with the computer simulation improved my ability to use new approaches, or ideas when called upon to solve a problem	4.34	0.87
Learning with the computer simulation improved my ability to solve new problems in physics by using basic principles and concepts	3.95	0.79

The researcher observed the students studied on the applets and worksheets in the computer laboratory class. The observation of the study was unstructured. The researcher' observation notes indicated that interacting with the well-designed applets helped students develop their own mental models and understanding of the physics concepts.

This was particularly helpful for topics of circuits. Students had enjoyable opportunity to explore basic concepts, as well as challenge, correct, add to his/her understanding of how world works. Similarly, students found exploring the applets fun and through this exploration, discovered new ideas about the physics.

When something unexpected happened, students questioned their understanding and changed parameters in the applet screen to explore the details. This behavior was in contrast to the way students approach to the experiments, covering same topic, using merely real-equipments. In those experiments, the many complex unknowns are mysterious, uncontrollable, and threatening.

For example, in DC-circuit lab students spent considerable time worrying about the significance of the color of plastic insulation on the wires. Besides, most of the students thought that their goal with such experiments was to reproduce preordained results as fast as possible, without making mistakes. In the applets application with real-equipments, students explored and changed the parameters easily without concerning with small details or worrying about the consequences.

However some students who just watched the applet without any action to understand it were not able to make sense of the physics. They must interact actively with the applet. Most of the learning occurred when the students was asking themselves questions that guide them exploration of the applet and their discovery of the answers.

CONCLUSION

According to the results of this study, it could be said that the computer simulations were able to improve students' learning outcomes compared to traditional physics learning. This finding supports the studies conducted by Azar & Şengüleç (2010); Bayrak (2008); Finkelstein & Pollock, 2005; Finkelstein et al. (2005); Finkelstein et al. (2006); Redish et al (1997). The results of the evaluation questionnaire toward computer simulations in this study were evaluated from two aspects which are pedagogical and technical.

When the results were evaluated from the point of the pedagogical, it could be said that students prefer learning with computer simulation than other learning procedures; while learning with the computer simulation, they felt challenged to do their best work; with the effort they put into it, they were satisfied with what they learned while learning with the computer simulation; learning with the computer simulation improved their understanding of the basic principles of physics; learning with the computer simulation improved their understanding of how theories can explain physical observation.

When the results were evaluated from the point of the technical, it could be said that the simulations support an interactive approach, employ dynamic feedback, follow a constructivist approach, provide a creative workplace, reduce unnecessary drudgery, make explicit otherwise inaccessible models or phenomena, and constrain students productively (Finkelstein et al., 2006). Also the present study suggests that carefully developed and tested educational applets in conjunction with real-equipments can be engaging and effective in students' understanding of the physics.

BIODATA AND CONTACT ADDRESS OF AUTHOR

He was born at Izmir, Turkey in 1976. He graduated his bachelor (1999) and Ph. D. (2006) from the Department of Physics Education, at University of Dokuz Eylul. He was Post Doctoral Fellow for two years (2008-2010) at Department of Physics in the Colorado School of Mines, Colorado, and USA. His research subjects are physics, science education and educational technology. He has been working as instructor at University of Dokuz Eylul, Izmir, Turkey since 2002.

Dr. Tolga GOK
University of Dokuz Eylul,
Torbali Technical School of Higher Education
35860, Izmir, TURKEY
Tel: +90 232 853 18 20
Fax: +90 232 853 16 06
E-mail: tolga.gok@deu.edu.tr

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