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Effectiveness of Computer Assisted Instructions and Cooperative Learning on Students' Conceptual Understanding about Electrostatics

Popat S. Tambade

Ramkrishna More ACS College, Akurdi, Pune, India

Abstract: In this study, the effects of interactive computer-based simulations and animations investigated in classroom on students' conceptual understanding of electrostatics. Three groups - one control group and two experimental groups of students at first year undergraduate level were studied to determine the role of computer simulations and animations in the development of functional understanding of the concepts of force, field and potential in electrostatics. The results of this study strongly support the fact that computer assisted instructions in cooperative group learning help students confront their cognitive constraints and foster a functional understanding of physics.

Key words: Computer-mediated communications · Improving classroom teaching · Simulations · Physics education · electrostatics.

INTRODUCTION

Over the last three decades, physics educators have begun to look more closely at what their students understand about physics concepts. Researchers showed that acquiring a conceptual understanding of physics has proven to be one of the most difficult challenges faced by the students. When students enter in the classroom they have some notions, beliefs and intuitions about how the world functions. Studies by different researchers worldwide have shown that students possess misleading conceptions of the nature of force and motion, which are extremely hard to overcome. These results are also observed in the areas of physics like mechanics, waves, optics, heat and thermodynamics, electricity and magnetism and quantum mechanics[1-3]. Research that has been done on conceptual understanding of physics and epistemologies indicates that many students lack solid conceptual understanding when taught by traditional method of instruction. They have epistemologies very different from scientists [4]. Research findings suggest that traditional lecture instruction is ineffective in dealing with students' misconceptions. It has been reported that interactive-engagement teaching methods are effective in conceptual learning of students as compared to traditional instructional method. These methods encourage students to make their understanding explicit through greater mental engagement and more extensive student-student and student-instructor interaction than does a typical traditional lecture class [5,6].

The use of computer technology in teaching environment provides wide-range of alternatives to students such as visualization of abstract concepts that will foster student understanding. Such alternatives would be complementary to traditional teaching [7]. Computer-aided instructional materials are more effective in developing favorable attitude and in capturing interest towards learning physics. Computer simulations seem to be one of the most effective ways to use computers in physics education. A variety of visual representations in the computer simulations make concepts visible that are otherwise invisible to students [8]. They encourage students to carry out the processes used in physics research: to question, predict, hypothesize, observe, interpret results etc. and also motivates and cultivates students' interest in learning physics and can heighten the individualized instruction by allowing students to proceed on their own pace and are able to go back to master the skills [9,10]. Simulations offer instructors the opportunity to provide students with an instructional tool that can help students transform their alternative science conceptions into correct science conceptions. Students could isolate and manipulate parameters and therefore

Corresponding Author: Popat S. Tambade, Ramkrishna More ACS College, Akurdi, Pune, 411044, India.
Tel : +91 20 66302104, Fax: +91 20 27659740, E-mail: pstam3@rediffmail.com.

help them to develop an understanding of the relationships among physical concepts, variables and phenomena [11]. Computer animations offer the potential for increased learning when there is a need for external visualization and when the content depends on an understanding of motion[12].

The present study aims to investigate whether computer assisted instruction with cooperative group learning is more effective than traditional instruction in increasing student success in physics at undergraduate level. The topic of "Electrostatics" was selected for instructions since it is hard to understand due to the abstract nature of the quantities such as field, flux and potential [13]. Students have difficulty to visualize the electrostatic fields. It has been observed that students have difficulty in interpretation of related vector representations and mathematical relationships [14]. Few students enter the course with personal experience with the subject. They have also problem in visualizing the movement and the direction of an electric charge in an electrical field [15]. By providing animations and simulations through computer assisted instructions (CAI) to students, it was aimed to help better understand the electrical processes without entirely depending on the mathematical definitions [16]. For this purpose Interactive Electrostatics Simulation Package (IESP) is developed.

Research Objectives: Objectives of this study were to develop and evaluate an interactive computer based animation and simulation package on Electrostatics and to provide first year undergraduate students of University of Pune with an interactive means of self-learning and evaluation.

Research Questions: To obtain data on various points of conceptual understanding in Electrostatics following research questions were set for the study.

- Student's ability to interpret verbal representations
- Student's ability to interpret vector representations
- Student's ability to interpret diagrammatic representations.
- Student's response to the questions posed in different representations

MATERIALS AND METHODS

Subjects: The subjects of this study were first year undergraduate students (aged 17 to 19) from Prof. Ramkrishna More College, Pune affiliated to Pune University in the academic year 2009-10. The students were randomly selected for three groups, Gropu-1(N = 21), Group-2 (N = 21) and Group-3 (N = 21).

Instruments: For data collection, an Electrostatics Concept Test (ECT) which is composed of 22 items of multiple choices was administered to subjects. The items in the ECT were selected from 35 items following expert's advice on the basis of level of difficulty and the indexes of defined differences. ECT covers the instructional objectives for the unit of Electrostatics. Students had to choose correct alternative for each item as well as give justification for the same. The reliability constant of the test has been determined according to Kuder-Richardson method and has been identified as 0.83.

Treatment: The traditional instruction was conducted over 12 lecture hours. The pretest was administered to 253 students at the end of traditional instruction. Students' difficulties were identified in the pretests on the basis of responses and justifications. The average difficulty index and average discrimination index of the test are 0.34 and 0.44 respectively. The instrument is very difficult and excellent discriminator.

After the pretest the students three groups viz. Group-1, Group-2, Group -3 were formed on the basis of random selection. During the experiments any data related to students who did not attend all activities, has been excluded from further analysis. As a result only data of 63 students' have been included in the analysis with each group of 21 students.

In Group 1, instructors used traditional method for revision of topics. The topics were revised in four lecture hours. During the revision instructors also solved some additional problems which included some conceptual and qualitative problems.

In Group-2, IESP was used as a support to traditional instructions. The topics of Electrostatics were revised for four lecture hours using the package and blackboard. The package was projected on a screen using LCD projector in the classroom. Students were observing the animations and simulations passively seating. The control and management are performed by the teacher. The students had no role in making changes in teaching materials. In this method, teacher is active, whereas the students are passive. This method is in support of traditional teaching method.

In Group-3, cooperative group learning method was used. The topics were revised for three lecture hours using the package and blackboard. After revision, subgroups, each of three students, were formed. One computer for each subgroup was provided and allowed to operate the package for three hours. Simultaneously, the IESP package was projected on a screen using LCD projector by the instructor. Worksheets were provided to students and asked to prepare answers for the questions provided in the worksheet. Necessary details have been explained with question-answer method and animations by the instructor. The students were given step by step instruction on how to use the package and asked to explore different parts of simulations embedded in it. In addition, they were assisted by instructor when they had any difficulties.

When the instructions have been completed, a posttest has been carried out.

Interactive Electrostatics Simulation Package: The Interactive simulation package applied in experimental group has been prepared with the help of Microsoft PowerPoint®, pictures and C programming. The content of the Electrostatics have been organized in the presentation which is in the form of six modules viz. Coulomb's law, Superposition Principle, Electric field, Electric potential, Gauss law and Electric Dipole. The text content in the PowerPoint slides is static as well as dynamic. Cognitive enhancement was maintained by using animations to figures and vector representations to teach concepts that were inaccessible through the textbook due to the lack of the textbook's ability to show motion. Forward and backward button facilities have been used in each slide. Simulations have been hyperlinked at appropriate positions in each module. Multiple choice questions and quizzes have been added at the end of each module. The multiple choice questions are different than that used in ECT. In simulations, students have the opportunity to observe the change in the force between two charges with variation of separation, resultant force for group of charges, magnitude and direction of electric intensity in the requested point in the field of point charges. It has been aimed to make sure that students develop their conceptual understanding by observing these changes.

RESULTS

Evidence for the effectiveness of teaching aimed at producing conceptual change may be provided by initial and final assessments of students' conceptual understanding. Based on the data obtained by ECT, the students' mean and standard deviation for pre and posttest scores for three groups were obtained. The pretest scores are presented in Table 1.

The independent sample t-test was used to determine whether there was a statistically significant mean difference between two groups for the pretest at 0.01 levels. The results are presented in Table 2, Table 3 and Table 4.

Table 2 shows t-test results of two mean scores of Group-1 and Group-2 at 0.01 significance level. Effect Size (d=0.043) and critical significance level $p > 0.01$ values indicates that there is no significance difference between mean scores in the pre-test.

Table 3 shows t-test results of two mean scores of Group-2 and Group-3 at 0.01 significance level. Effect Size (0.021) and critical significance level $p > 0.01$ values indicates that there is no significance difference between mean scores in the pre-test.

Table 4 shows t-test results of two mean scores of Group-2 and Group-3 at 0.01 significance level. Effect Size (0.067) and critical significance level $p > 0.01$ values indicates that there is no significance difference between mean scores in the pre-test.

These results indicate that the subjects in the three groups that have participated in the research are equal in terms of knowledge according to their t-test results.

In order to investigate the effect of IESP approach on students' achievement on conceptual understanding about electrostatics, a normalized gain g for each student was obtained by using the equation

$$g = \frac{\text{Posttest score-pretest score}}{\text{100-pretestscore}}$$

Class average normalized gain <g> with standard deviation was obtained for each group [5]. According to Hake R. (1998), the treatment given to be interactive, if <g> is greater than 0.3. To determine whether there are any differences between two groups based on the average normalized gains, the calculated gains have been subjected to t-test analysis.

Table 1: Pretest scores of three groups

Group	N	Mean Score	Standard Deviation
Group-1	21	33.98	10.02
Group-2	21	33.55	10.51
Group-3	21	33.33	9.78

Table 2: t-test analysis of pre-test findings of Group-1 and Group-2

Group	N	Mean Score	Standard Deviation	t (0.01)	p	d
Group-1	21	33.98	10.02	0.137	0.446	0.043
Group-2	21	33.55	10.21			

Table 3: t-test analysis of pre-test findings of Group-1 and Group-2

Group	N	Mean Score	Standard Deviation	t (0.01)	p	d
Group-2	21	33.55	10.51	0.067	0.474	0.021
Group-3	21	33.33	9.78			

Table 4: t-test analysis of pre-test findings of Group-1 and Group-3

Group	N	Mean Score	Standard Deviation	t(0.01)	p	d
Group-1	21	33.98	10.02	0.212	0.416	0.067
Group-3	21	33.55	9.78			

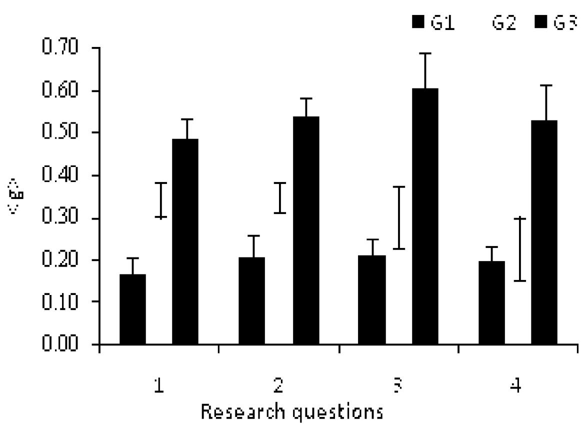

Fig. 1: Gains on conceptual understanding using reserach questions

The post-test scores and average normalized gains are presented in Table 5.

The results of the analysis for comparison between two groups have been provided in the Table 6, Table 7 and Table 8.

Table 6 shows t-test results of class average normalized gains of Group-1 and Group-2 at 0.01 significance level. Effect Size (1.39) and critical significance level $p < 0.01$ values indicates that there is significance difference between normalized gains in the pre-test and post-test comparison. The computer package used in support of traditional instruction helps to increase achievement in physics.

Table 5: Post-test findings of groups

Group	N	Mean Score	Standard Deviation	<g>	S
Group-1	21	43.94	8.78	0.150	0.06
Group-2	21	54.11	11.13	0.305	0.149
Group-3	21	70.35	9.38	0.556	0.136

(S = standard deviation for normalized gain for g)

Table 6: t-test analysis of post-test findings of Group-1 and Group-2

Group	N	<g>	S	t - value (0.01)	p	d
Group-1	21	0.150	0.060	4.417	3.72×10^{-5}	1.39
Group-2	21	0.305	0.149			

Table 7: t-test analysis of post-test findings of Group-1 and Group-3

Group	N	<g>	S	t - value(0.01)	p	d
Group-1	21	0.150	0.06	12.52	1.01×10^{-15}	3.96
Group-3	21	0.556	0.136			

Table 8: t-test analysis of post-test findings of Group-2 and Group-3

Group	N	<g>	S	t - value(0.01)	p	d
Group-2	21	0.305	0.149	5.69	6.44×10^{-7}	1.80
Group-3	21	0.556	0.136			

Table 7 shows t-test results of class average normalized gains of Group-1 and Group-3 at 0.01 significance level. Effect Size (3.96) and critical significance level $p < 0.01$ values indicates that there is significance difference between average normalized gains in the pre-test and post-test comparison. The computer package used in cooperative group learning is more effective than traditional instruction in students' achievement in learning physics.

Table 8 shows t-test results of class average normalized gains of Group-2 and Group-3 at 0.01 significance level. Effect Size (1.80) and critical significance level $p < 0.01$ values indicates that there is significance difference between average normalized gains in the pre-test and post-test comparison. These results indicate that the cooperative group learning method with computer assisted instruction is more effective than passive learner computer assisted instruction method. The computer package used in cooperative group learning is more effective than used in support of traditional instruction in students' achievement in learning physics.

This research showed the result that Computer Assisted Instruction was pretty much more effective than traditional teaching in students' achievement in physics. For the analysis of research questions, the items in the test were grouped according to type of research questions. The normalized gains for three groups on research questions are shown in Figure 1.

As it is shown in Figure 1, the normalized gains in each research question for Group-3 is more as compared to the normalized gain for Group-2. The average normalized gain for Group -2 is greater than that of Group-1. Thus the treatment used for Group-3 and Group-2 is interactive and produces significant change in the conceptual understanding of students. The Group-3 evidenced a significantly greater degree of conceptual change and was higher than Group-2.

DISCUSSION

During analysis of students' responses in pretest certain difficulties were observed in the students' conceptual understanding. Students have profound difficulties in understanding Coulomb's law, Gauss law, superposition principle, electric field and potential. Most of the difficulties are due to students difficulties in understanding vector representations. The knowledge of vector is very crucial especially for understanding concepts in electrostatics. It is also observed that the students have poor reasoning ability.

It has been found that the Effect Size and critical significance level $p > 0.01$ values which were obtained from pretest showed the result that students in the three treatment groups have similar in terms of their knowledge.

The Effect Size and t-test obtained from class average normalized gains for group-1 and group-2, group-1 and group-3, in this research showed the result that Computer Assisted Instruction was much more effective than traditional teaching in students' achievement in physics.

It is observed that computer visualization of concepts from the electrostatics enhanced students' ability to transfer the concepts from the abstract level to the concrete level, thereby, improving their conceptual understanding of electrostatic phenomena [16]. Computer aided visualization of Coulomb's law using computer simulations helps students to understand the variation of force with the distance as well as the direction of forces. The simulations of electric field of point charges enabled students to understand the variation of electric intensity and potential at different points in the field as well as equi-potential surfaces. It is observe that animations and simulations helped the students to understand the vector diagram and principle of superposition which may not be as observable as done inside an ordinary classroom set-up [10].

The analysis of research questions showed that the students in Group-2 and Group-3 were better placed in interpretation of verbal, vector representations and diagrammatic representations in electrostatics as compared to Group-1. They are also more coherent in conceptual understanding as compared to their counter parts. Our results indicate that students significantly improved their conceptual understanding of the subject matter [17].

The worksheets provided to Group-3 students helped to build a coherent conceptual understanding. These worksheets acted as an instructional support to the CAI. The cooperative learning strategy used for this group showed that it is much more effective than the use of CAI in classroom with students as passive listeners. It has been observed that CAI improves student's success as well as develops high level of thinking abilities. Students learn the concepts by comprehension rather than memorizing [18]. When students use a complex simulation, a group learning context may be more effective than an individual learning context [19].

The results of this study shows that teaching of "Electrostatics" performed with animations and simulations in the scope of Computer Assisted Instruction with cooperative learning is a more productive approach than the teaching performed with traditional methods in terms of improving the student success and concept understanding [16]. Teachers can easily use animations and simulations of vector representations instead of trying to draw and show these on the blackboard [20].

CONCLUSION

In conclusion, authors have shown that computer-assisted instructions are an excellent way to focus students' understanding of principles in Electrostatics. The use of the CAI improved the students' ability to make acceptable predictions and explanations of the phenomena in physics. Findings of this study strongly support the fact that Computer animations and simulations may be used as an alternative instructional tool, in order to help students confront their cognitive constraints and develop a functional understanding of physics. To increase effects of CAI authors strongly believe that instructional support must be provided with simulations and animations. The findings confirm that computer-assisted instructional material in physics motivates and cultivates students' interest in learning physics and they have the ability to engage students in a way that other pedagogical tools cannot. Through animations and simulations, teachers can easily demonstrate the laws, concepts and modeling processes in physics to their students without losing his/her role as the learning guide in the classroom.

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