

Enhancing the Learning of Thermodynamics using Computer Assisted Instructions at Undergraduate Level

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Received: 15 April 2012 – Revised: 08 August 2012 – Accepted: 16 August 2012

Abstract

In this study, the effects of interactive multimedia package were investigated in classroom on students' conceptual understanding of heat and thermodynamics. Two groups – one control group and one experimental group of students at first year undergraduate level were studied to determine the role of computer animations in the development of functional understanding of the concepts of thermodynamics. For this purpose, interactive multimedia package on thermodynamics is developed. Thermodynamics Concept Test was administered to test students' conceptual understanding. The difficulty index and discrimination index of the test are 0.402 and 0.31 respectively. The results of the study showed that the interactive method used for experimental group is helpful in students' achievement in thermodynamics. The results of this study strongly support the fact that multimedia assisted instructions in cooperative group learning help students confront their cognitive constraints and foster a functional understanding of physics.

Keywords: Computer-mediated communications, Improving classroom teaching, Physics education, Thermodynamics, heat engines.

Introduction

Physics Education 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 physics class, they have some notions, beliefs and intuitions about how the world functions. Worldwide Physics education research (PER) 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 (Maloney et al., 2001; McDermott, 2001; Meltzer, 2005). Physics education researchers studied the students' conceptual understanding about heat, temperature, internal energy, ideal gas laws etc. Their investigation showed that students have conceptual difficulties as well as misconceptions regarding the concepts of heat and thermodynamics (Tanahoung, Chitaree & Soankwan, 2010; Kautz et al., 2005; Loverude, Kautz & Heron P, 2002).

Research findings of PER showed that traditional lecture instruction is ineffective in dealing with students' misconceptions. Researchers and Physics Educators have been reported

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that interactive- engagement teaching methods are effective in conceptual learning of students as compared to traditional instructional method. These methods have ability to 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 (Hake, 1998; Meltzer & Manivannan, 2002; Thacker, 2003).

The use of computer assisted teaching for physics in classroom environment provides wide-range of alternatives to students such as visualization of abstract concepts, graphical representations through animations and simulations. These alternatives would be complementary to traditional teaching and are able to develop favorable attitude as well as foster student understanding (Hake, 1998). Computer simulations have ability to encourage students to carry out the processes used in physics research: to question, predict, hypothesize, observe, interpret results etc. They can also motivate and cultivate students' interest in learning physics. Simulations may be used for individualized instruction by allowing students to proceed on their own pace and are able to go back to master the skills (Finkelstein et al., 2005; Holec, Spodniaková Pfefferová & Raganová, 2004; Ubiña & Patricio, 2007). Using simulations students could isolate and manipulate parameters and therefore help them to develop an understanding of the relationships among physical concepts, variables and phenomena (Tao & Gunstone, 1999). Computer animations offer students potential of learning when there is a need for external visualization and when the content depends on an understanding of motion (Dancy & Beichner, 2006).

The present study aims to investigate whether computer assisted instruction is more effective than traditional instruction in increasing student success in physics at undergraduate level. The topic of “Thermodynamics” was selected for instructions since it is hard to understand due to the abstract nature of the quantities such as concept of heat, equation of state and thermodynamics processes. Researchers showed that students have difficulties to understand the basic concept of heat and work, the basic concept of entropy, and thermodynamic processes (Yeo & Zandik, 2001). Therefore students have difficulties for understanding of first law of thermodynamics and how to apply for problem solving. The students also have difficulties how to apply P-V diagram for problem solving. Researcher found that students have misinterpretation of understanding of ideal gas laws (Christensen, Meltzer & Ogilvie, 2009; Meltzer, 2004; Meltzer, 2006). The students frequently failed to differentiate the concepts of heat, temperature, work and internal energy. The students have difficulties of understanding the role of entropy in the second law of thermodynamics (Loverude, Kautz & Heron, 2002; Thacker, 2003).

Junglas (2006) studied effect of thermodynamics simulations on conceptual understanding of engineering students. He found that students' reactions to the applets are very positive and they take more active part in the lecture and average score of the final examinations has been increased. Physlets are developed to help students visualize abstract concepts and make connections between mechanics and thermodynamics. In the process, students develop a more solid conceptual understanding of thermodynamic processes in introductory physics (Cox et al., 2003).

The present study aimed to provide animations and simulations through computer assisted instructions (CAI) to students to help better understand the thermodynamics processes without entirely depending on the mathematical formulation (Junglas, 2006). For this purpose Interactive Thermodynamics Multimedia Package (ITMP) is developed.

Research Objectives

Objectives of this study were to develop and evaluate an interactive multimedia animation package on Thermodynamics 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 Thermodynamics, following research questions were set for the study.

- (1) Student's ability to interpret verbal representations in thermodynamics.
- (2) Student's ability to interpret equations in thermodynamics.
- (3) Student's ability to interpret graphical representations.

Materials and Methods

Pretest-posttest experimental procedure is used for the study. In this study the effect of computer assisted instruction is studied.

Subjects

The subjects of this study were first year undergraduate students (aged 17 to 19) from Prof. Ramkrishna More College, Pune and Hutatma Rajguru College, Rajgurunagar, Pune affiliated to Pune University in the academic year 2011-12. The students were randomly selected for two groups, Group-1(N =30) as experimental group, Group-2 (N = 30) as control group.

Instruments

For data collection, a Thermodynamic Concept Test (TCT) which is composed of 24 items of multiple choices was administered to subjects. The items in the TCT were selected from 35 items following expert's advice on the basis of level of difficulty and the indexes of defined differences. The topics covered in the TCT are laws of thermodynamics, concept of heat, equation of state, isothermal, adiabatic, isochoric processes and Heat engines. The test was validated from ten senior most teachers who are teaching heat and thermodynamics. The reliability coefficient of the test has been determined according to Kuder-Richardson (KR-21) method and has been identified as 0.70.

Treatment

The traditional instruction was conducted over 15 lecture hours. The pretest was administered to 156 students at the end of traditional instruction. Students' conceptual difficulties were identified in the pretests on the basis of responses. The average difficulty index and average discrimination index of the test were found to be 0.402 and 0.31 respectively.

The average point biserial coefficient for TCT is 0.43, which is greater than the criterion value 0.2, so TCT items overall have fairly high correlations with the whole test. Fergusson delta for the test is 0.93, which is greater than 0.9. Since $D > 0.3$ and Fergusson delta > 0.9 , the test is considered to offer good discrimination (Ding et al., 2006; Day & Boun, 2011). Thus, instrument is moderately difficult and good discriminator.

After the pretest, the students were divided into two groups' viz. Experimental group and control group 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 60 students' have been included in the analysis with each group of 30 students.

For control group the topics were revised using traditional method. The topics were revised in five lecture hours. During the revision, instructors also solved some additional problems which included some conceptual and qualitative problems.

For experimental group, Computer animations and simulations package was used as a support to traditional instructions. The topics of Thermodynamics were revised for six 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 as well as simultaneously prepared their notes. 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. Worksheets were provided to students and asked to prepare answers for the questions provided in the worksheet. The students' activities were monitored during this exercise. The help was provided whenever necessary. When the instructions have been completed, a posttest has been carried out.

Multimedia Package

The ITMP applied in experimental group has been prepared with the help of Macromedia Flash, Microsoft PowerPoint®, and C programming. The content of the Thermodynamics have been organized in the presentation which is in the form of six modules viz. Concept of heat, Equation of state, Thermodynamics processes, Carnot engine, Otto engine and Diesel engine. The text content in the PowerPoint slides is static as well as dynamic. Cognitive enhancement was maintained by using animations to figures 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. Flash animations and 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 TCT. In simulation, students have the opportunity to observe the change in the volume or pressure with change in temperature. It has been aimed to make sure that students develop their conceptual understanding by observing these changes. Figure 1 shows screenshot of animation on Otto engine.

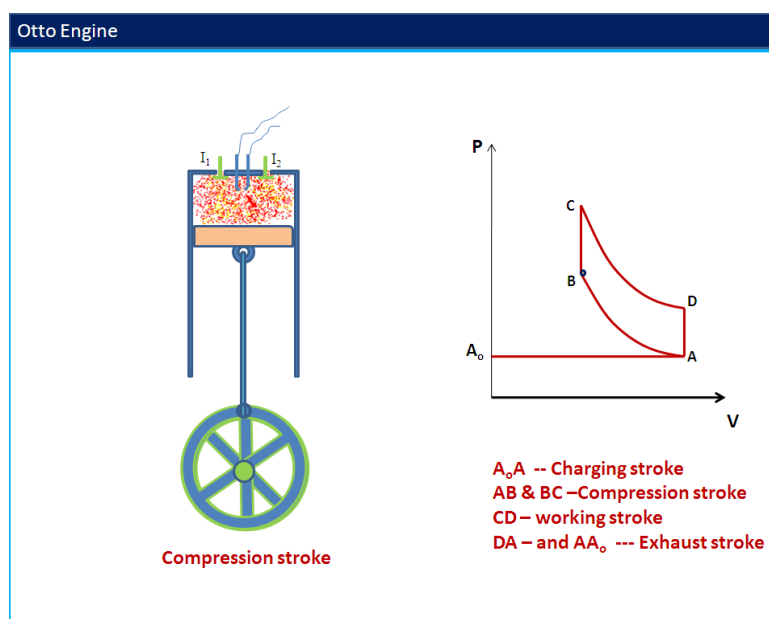


Figure 1. Screenshot of animation on Otto engine.

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 TCT, the students' mean and standard deviation for pre and posttest scores for two groups were obtained. The pretest scores are presented in Table 1.

Table 1. Pretest scores of two groups

Group	N	Mean Score	Standard Deviation	t (0.01)	p	d
Control	30	42.64	12.56	0.07548	0.470	0.0198
Experimental	30	42.36	15.97			

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 1.

Table 1 shows t-test results of two mean scores of Group-1 and Group-2 at 0.01 significance level. Effect Size ($d=0.0198$) 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 two 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 multimedia package approach on students' achievement on conceptual understanding about thermodynamics, a normalized gain g for each student was obtained by using the equation

$$g = \frac{\% Posttest - \% pretest}{100 - \% pretest}$$

Class average normalized gain $\langle g \rangle$ with standard deviation was obtained for each group. According to Hake (1998) the treatment given to be interactive, if $\langle g \rangle$ 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.

The post-test scores and average normalized gains are presented in Table 2.

Table 2. Post-test findings of groups

Group	N	Mean Score	Standard Deviation	$\langle g \rangle$	S
Control	30	56.25	9.832	0.2244	0.1463
Experimental	30	72.78	8.597	0.50	0.1734

(S = standard deviation for normalized gain for g)

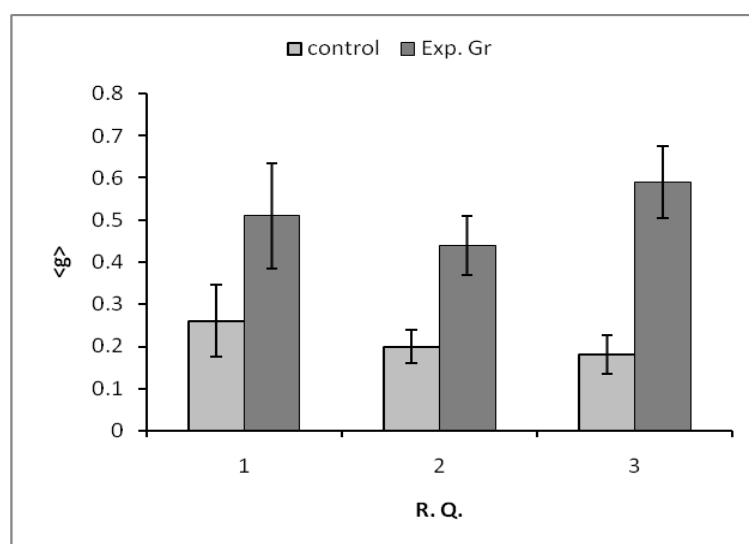
The results of the analysis for comparison between two groups have been provided in the Table 3.

Table 3: t-test analysis of post-test findings of Experimental and control groups

Group	N	$\langle g \rangle$	S	t – value (0.01)	p	d
Control	30	0.2244	0.1463	6.66	5.43×10^{-9}	1.75
Experimental	30	0.5003	0.1734			

(S = standard deviation for normalized gain for g)

Table 3 shows t-test results of class average normalized gains of Control and Experimental group at 0.01 significance level. Effect Size (1.75) 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.

**Figure 2.** Gains on conceptual understanding using research questions

This research showed the result that Computer Assisted Instruction was pretty and 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 control and experimental groups are shown in Figure 2. As it is shown in Figure 2, the normalized gains in each research question for experimental group is more as compared to normalized gain for control group. The experimental group evidences a significantly greater degree of conceptual change and was higher than control group.

Discussion

During analysis of students' responses in pretest certain difficulties were observed in the students' conceptual understanding. Students have profound difficulties in understanding thermodynamic processes, gas laws and heat engines. Most of the difficulties are due to students' difficulties in understanding of PV diagrams, work and internal energy (Christensen, Meltzer & Ogilvie, 2009; Meltzer, 2004; Meltzer, 2006).

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 two treatment groups have similar in terms of their conceptual understanding.

The Effect Size and t-test obtained from class average normalized gains for experimental group and control group in this research showed 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 thermodynamics enhanced students' ability to transfer the concepts from the abstract level to the concrete level, thereby, improving their conceptual understanding of thermodynamics phenomena (Cox et al., 2003; Junglas, 2006). Computer aided visualization of heat engines using computer animations helps students to understand the working of engine with variation of temperature of sink and source. It is observe that animations and simulations helped the students to understand the PV diagram, isobaric, adiabatic, and isothermal processes which may not be as observable as done inside an ordinary classroom set-up.

The analysis of students' responses on posttest showed that the students in experimental group were better placed in interpretation of verbal representations in thermodynamics as compared to control group. They are also better placed in interpretation of equations and indicator diagrams to their counter parts. Our results indicate that students significantly improved their conceptual understanding of the subject matter.

The worksheets provided to experimental group students helped to build a coherent conceptual understanding. These worksheets acted as an instructional support to the CAI. With the help of worksheets students were able to interpret different representations. 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. The results of this study shows that teaching of "Thermodynamics" 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.

Conclusions

In conclusion, authors have shown that computer-assisted instructions are an excellent way to focus students' understanding of principles in Thermodynamics. The use of the CAI improved the students' ability to make acceptable predictions and explanations of the phenomena in thermodynamics. Positive intervention of Computer animations and simulations in classroom makes the real difference in student learning such as interpretation of verbal and graphical representations as well as equations in thermodynamics. 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. Readers may seek a copy of diagnostic test used in the study by mailing the authors.

Suggestions for future research

Technically sophisticated simulations, animations, and multimedia representations of advanced topics in thermodynamics should be developed and implemented in undergraduate physics classroom. The effect of such tools must be probed under different conditions. Such research is crucial for further development and implementation of computer-based instructional tools in physics.

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