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The Impact of PBL on Undergraduate Physics Students' Understanding of Thermodynamics

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Abstract
Lecture method is still need to a part of PBL in order to explain the difficult and abstract concepts in all fields of physics particularly thermodynamics. Introducing and promoting PBL in the lecture method is wise step for innovation in teaching and learning. The objective of this study is to compare the effects of using three methods: problem-based learning (PBL), PBL with lecture method, and conventional teaching on undergraduate physics students' understanding of thermodynamics. The actual sample size comprises of 122 students, who were selected randomly from the Physics Department, College of Education in Iraq in the academic year 2011-2012. In this study, the pre- and post-test were done and the instruments were administered to the students for data collection. The data was analyzed and the statistical results rejected null hypothesis of this study. The study revealed that using PBL or PBL with lecture method promotes understanding of thermodynamics superior than using conventional teaching method, also the PBL with lecture method enhances understanding of thermodynamics better than using PBL alone, among the physics undergraduates in Iraq.

Keywords: Problem-Based Learning, Pbl With Lecture Method, Conventional Teaching, Understanding of Thermodynamics.

Introduction

Science and its applications are part of daily life to make our life better and therefore the development of an individual's understanding of science and its applications is one of the objectives of science instruction (Adiguzel, 2006). In the modern era, most countries have shown increasing interest in teaching and learning science and they expend efforts to develop science education (Kavsut, 2010; Ozmen, 2004). Science education is needful in every phase of life and is strongly related to the active notion of teaching science (Aydogan, Gunes, & Gulcicek, 2003; Kavsut, 2010).

Moreover, the teaching of science and understanding of its concepts has become important now more than ever (Montero & Gonzalez, 2009; Sahin, 2010). Conceptual understanding of science involves the use of new strategies by teachers for better learning and teaching of science to help students understand science concepts (Bouwma-Gearhart, Stewart, & Brown, 2009; Cakir Olgun, 2008; Miller, Streveler, Yang, & Santiago Roman, 2009; Rascoe, 2010).

Literature on physics education has shown that students have abundant difficulties in understanding physics concepts in all topics of physics (e.g., Gonen & Kocakaya, 2010; Maloney, O'kuma, & Hieggelke, 2001; Martin-Blas, Seidel, & Serrano-Fernández, 2010), and particularly in the concepts of thermodynamics (e.g., Miller, Streveler, Yang, & Santiago Roman, 2009; Nottis, Prince, & Vigeant, 2010; Rascoe, 2010). Understanding the distinctions among heat, energy, and temperature in physics can be difficult for students at all levels of education, including those in science education. Difficulties of understanding the physics concepts on heat transfer continue even after students successfully complete relevant coursework (Nottis, Prince, & Vigeant, 2010).

To realize the problem deeply, the students should have authentic previous information (Norman & Schmidt, 1992). Activation of previous information lets learners to compose a fundamental structure where new knowledge is added. If learning is an effective procedure and constructs on prior information, this can likely lead to successful storage of recent knowledge. Prior knowledge needs to be activated to know recent knowledge, as well as to build on new knowledge, which is useful in the future professional life of the student (Xiuping, 2002).

Researchers have described the relative effectiveness of different pedagogical approaches in helping students understand physics concepts, such as heat, energy, and temperature. They encourage removing the difficulties of understanding physics concepts among students through their identification and through development of strategies which supply learners with exact and conceptual knowledge needed for solving problems in physics. One of the most effective approaches in addressing these difficulties is to understand the physics concepts through problem-based learning (PBL), which is a scientifically accurate model (Bouwma-Gearhart, Stewart, & Brown, 2009; Cakir Olgun, 2008; Miller, Streveler, Yang, & Santiago Roman, 2009). PBL is a student-centred teaching approach that enables students to become active participants in solving problems, answering questions (Ates & Eryilmaz, 2011). According to Hmelo-Silver (2004), PBL as a teaching method, is based on students-centered learning, where students learn through simplified problem solving and where problems should be complex, ill-structured, and real.

Problem Statement

To reach the top step of science teaching requires the realization and understanding of the science concepts (Kavsut, 2010). Several educational studies focus on the difficulties and troubles confronted by science students inhibiting the understanding of science concepts (e.g., Baser, 2006; Bouwma-Gearhart, Stewart, & Brown, 2009; Cahyadi & Butler, 2004; Cakir Olgun, 2008; Polanco, Calderón, & Delgado, 2004; Posner, Strike, Hewson, & Gertzog, 1982; Rascoe, 2010; Savinainen, Scott, & Viiri, 2004; Schmidt, Marohn, & Harrison, 2007; Thijs & Dekkers, 1998; Usta & Ayas, 2010).

The difficulties negatively affects the students' next stage of learning (Canpolat, Pinarbasi, Bayrakceken, & Geban, 2004; Cepni, Tas, & Kose, 2006; Martin-Blas, Seidel, & Serrano-Fernández, 2010; Usta & Ayas, 2010). More importantly, many of these difficulties in understanding physics concepts are widespread and have a detrimental effect on problem solving (Brown, 1992; Champagne, Gunstone, & Klopfer, 1982). Many of these constructs of science concepts lead students to formulate incorrect schema about the nature of concepts in science, particularly in physics (Slykhius, 2005). Past studies on physics show that students have several obstacles in understanding most of its topics (e.g., Gonen & Kocakaya, 2010; Maloney, O'kuma, & Hieggelke, 2001; Martin-Blas, Seidel, & Serrano-Fernández, 2010).

Numerous studies focused on the impediments on all physics topics, particularly thermodynamics concepts (e.g., Nottis, Prince, & Vigeant, 2010; Rascoe, 2010; Miller, Streveler, Yang, & Santiago Roman, 2009). Rozier and Viennot (1991) point out that "thermodynamics is a subject that involves multivariable problems and obvious difficulties" (p. 3). Problems of the understanding thermodynamics can continue even after students successfully complete their coursework (Nottis, Prince, & Vigeant, 2010; Self, Miller, Kean, Moore, Ogletree, & Schreiber, 2008). Science students in introductory level often have difficulty distinguishing between thermal physics concepts, such as heat and temperature (Carlton, 2000). Gonen and Kocakaya (2010) report that students may be enabled to address difficulties of concepts and understand science concepts, particularly thermodynamics, by developing approaches and strategies that centre on certain concepts. Actually, one of the most successful approaches is problem-based learning (PBL) (Prince, 2004; Sahin, 2009; van Berkel & Schmidt, 2005).

To address and overcome the aforementioned problems and challenges on difficulties of understanding the abstract physics concepts, particularly in thermodynamics, the researcher proposes this study of using PBL to enable students to understand thermodynamics. It is more efficient than traditional science teaching method, under the traditional teacher-centred learning assumes that a teacher guides the students and offers them new information. The focus of teaching is on the transmission of knowledge from the expert teacher to the novice learner (Cheong, 2008).

The role of students, in the conventional manner, is passive rather than an active, thus hindering learning and understanding of science concepts. Under the conventional manner, students listen and watch, and most teaching time is spent with the instructor lecturing. To enable understanding of the content, students are required to individually work on tasks, and collaboration is encouraged, in the traditional method, a teacher is required to have effective writing and speaking skills (Azu & Osinubi, 2011; Cheong, 2008). Therefore, there is a need to adopt PBL for solving the problem of the traditional science teaching method.

To enhance a deeper understanding of the content, the interaction between the problem and use of knowledge must be done. PBL environment establishes the relationship between the knowledge and its use (Ball & Pelco, 2006). The problems used are real-life situations that they may face in the future and are educationally sound. Problems have "ill-structured feature help students learn a set of important concepts" (Gallagher, 1997, p. 338). Instructors in PBL are more creative with their teaching while old methods, which are based on boring lectures and memorization of material, are challenged with this delivery method (Ates & Eryilmaz, 2011; Sulaiman, 2011).

According to McParland, Noble and Livingston (2004), the PBL curriculum is significantly more successful than the previous, traditional course. Tang, Yu, Jiang, Zhang, Wang and Huang (2008) pointed out that PBL is accepted by most students and teachers as a teaching method, and is believed to improve understanding ability. In PBL, student-centred learning method shifts the concentration of effectiveness from the instructor to the students to reduce teacher-centred learning (Ates & Eryilmaz, 2011; Ball & Pelco, 2006; Cheong, 2008; Subramaniam, Scally, & Gibson, 2004).

It is worth mentioning, using the PBL approach alone and adopting it only as a teaching method, is considered risky because it entails complete shift from a teacher-centred learning in conventional manner to another student-centred learning in the PBL. PBL, as an instruction process, centers on the precept of using problem, which should be complex and ill-structured, that will lead to drastic change in learning approach. Under the PBL method, students are encouraged to be active rather than passive and cooperate rather than compete (Cheong, 2008). Incorporating PBL into traditional method could be a useful tool to reinforce material covered in traditional lecture, and can be a positive influence on the learning process (Liceaga, Ballard & Skura, 2011). Saalu, Abraham and Aina (2010) point out that "there should be an intelligent combination of using both the traditional and PBL approaches for teaching anatomy which may provide the most effective training for undergraduate medical student" (p. 197).

In the current study, the problems for PBL were developed in material of thermodynamics in the field of physics, to investigate the understanding of thermodynamics in order to minimize the difficulties and obstacles among physics undergraduates.

Objective of the Study

The purpose of this study is to compare the effects of using three methods which are PBL, the PBL with lecture method, and the conventional teaching, on understanding of thermodynamics among physics undergraduates.

Research Question

Are there significant differences on the linear combination of posttest mean scores of understanding of thermodynamics among physics undergraduates who followed PBL, the PBL with lecture method, and the conventional teaching after the effect of mean scores of pretest is controlled?

Research Hypothesis

There are no significant differences on the linear combination of posttest mean scores of understanding of thermodynamics among physics undergraduates who followed PBL, the PBL with lecture method, and the conventional teaching after the effect of pretest mean scores is controlled.

Methodology

Research Design

This study followed a quasi experimental research method, nonequivalent control group design to measure the effect of problem-based learning (PBL) as the teaching method alone or with the lecture method (PBL with lecture method) on the understanding of thermodynamics among physics undergraduates, compared with the conventional teaching method.

The sample consisted of three groups of the physics undergraduates. The first experimental group used PBL treatment, and the second experimental group used the PBL with lecture method treatment, while the third group was a control group and it used conventional teaching. The number of items in thermodynamics understanding test consists of 16 items. The instruments were administered to whole groups before and after the treatments.

Population and Sample

The population for this study comprised of physics undergraduates male and female (176) students enrolled in the Physics Department, College of Education in Baghdad Iraq, for academic year 2011-2012. The actual sample size is 122 physics undergraduates who study in the Physics Department, College of Education in Baghdad Iraq, in the second session of academic year 2011-2012. They were randomly selected from the college.

Distribution of Groups

Three groups followed teaching methods which are the PBL method, the PBL with lecture method, and the conventional teaching method. The frequency of each group is 42 subjects for the PBL, 39 subjects for the PBL with lecture method, and 41 subjects for the conventional teaching.

Instrument of the Study

The instrument of this study is thermodynamics understanding test consisted of 16 multiple-his choice items. Before the treatment, a pretest was administered to the physics undergraduates to measure student's prior knowledge on thermodynamics understanding. After the treatment, a posttest was administered to the physics undergraduates to measure their new knowledge on thermodynamics understanding. The difference between pretest and posttest results on the thermodynamics understanding determined the effectiveness of three teaching methods, which are PBL, the PBL with lecture method, and conventional teaching on students' understanding of thermodynamics. The items of thermodynamics understanding test were adapted based on the introductory thermodynamics understanding test of Yeo and Zadink (2001).

Findings

The univariate test of statistical significance has been applied to examine the hypothesis which stated that:

> *There are no significant differences on the linear combination of mean scores of posttest of understanding of thermodynamics among physics undergraduates who followed PBL, the PBL with lecture method, and the conventional teaching after the effect of mean scores of pretest is controlled.*

The results revealed univariate test of statistical significance on the differences observed in the scores of posttest across the various groups, as shown in Table 1.

Table 1

Univariate Analysis of Subjects' Posttest Scores of Understanding of Thermodynamics in Various Groups

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Posttest of understanding	768.07[a]	5	153.61	54.86	.00
Intercept	Posttest of understanding	48.85	1	48.85	17.45	.00
Pretest of understanding of thermodynamics	Posttest of understanding	470.19	1	470.19	167.91	.00
Group	Posttest of understanding	188.77	2	94.39	33.71	.00
Error	Posttest of understanding	324.82	116	2.80		
Total	Posttest of understanding	14106.0	122			
Corrected Total	Posttest of understanding	1092.89	121			

a. *R* Squared = .70 (Adjusted *R* Squared = .69)

The scores of posttest on the understanding of thermodynamics across the various groups with $F(2, 116) = 33.71$, Mean Square = 94.39 and $P = .00$. Therefore, these differences in the scores of posttest on the understanding of thermodynamics among three groups were significant. So, the statistical results rejected the null hypothesis.

Thus, there were significant differences on the linear combination of posttest mean scores of the understanding of thermodynamics among physics undergraduates who followed PBL, the PBL with lecture method, and the conventional teaching method.

Overall, the results of comparison among three groups of the PBL method, the PBL with lecture method, and the conventional teaching method indicated that there were statistical significant differences.

Table 2 explains a summary of post hoc pairwise multiple comparisons across the various groups of the PBL method, the PBL with lecture method, and the conventional teaching method.

Table 2

Summary of Post Hoc Pairwise Multiple Comparisons Observed Means Scores of Posttest of Understanding of Thermodynamics

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Posttest of understanding of thermodynamics	(1) PBL	PBL with lecture	-2.19*	.58	.00
		conventional	1.61*	.57	.01
	(2) PBL with lecture	PBL	2.19*	.58	.00
		conventional	3.80*	.58	.00
	(3) conventional	PBL	-1.61*	.57	.01
		PBL with lecture	-3.8*	.58	.00

*. The mean difference is significant at the .02 level.

Statistical results showed there were significant differences, with *P* < .02 on posttest mean scores of the understanding of thermodynamics between the PBL method of first group and the conventional teaching method of third group, with Mean Difference = 1.61*, in favor of the PBL method which was better than conventional teaching method. Likewise, there were statistically significant differences, with *P* < .02 on mean scores of posttest of the understanding of thermodynamics between the PBL with lecture method and the conventional teaching method, with Mean Difference = 3.80*, in favor of the PBL with lecture method which was superior and better than the conventional teaching method.

In addition, there were statistically significant differences, with *P* < .02 on mean scores of posttest of the understanding of thermodynamics between the PBL method and the PBL with lecture method, with Mean Difference = 2.19*, in favor of the PBL with lecture method which was better than the PBL method. Thereby, the PBL with lecture method was better than the other methods. Overall, the PBL without/ with lecture method was better than the conventional teaching method. So, using the PBL with lecture method enhances the understanding of thermodynamics among physics undergraduates better than the PBL method.

Discussion

Overall, the experimental treatment of PBL with lecture method was able to enhance understanding of thermodynamics better than other treatments like PBL method among physics undergraduates. Posttest means scores of students on the understanding of thermodynamics who followed PBL with lecture method showed superior understanding of thermodynamics than their peers who followed PBL method alone or the conventional teaching method. In other words, students who followed PBL with lecture method demonstrated the greatest ability among the three groups to correctly answer multiple-choice posttest items on the understanding of thermodynamics.

The statistical results rejected the hypothesis posed in this study, which stated that "There are no significant differences on the linear combination of posttest mean scores of understanding of thermodynamics among physics undergraduates who followed PBL, the PBL with lecture method, and the conventional teaching after the effect of mean scores of pretest is controlled".

This finding revealed that using PBL with lecture method enhances deeper understanding of thermodynamics than other treatments like PBL method alone. This means that students who followed the PBL with lecture method better understood of thermodynamics compared with students who followed PBL only. Therefore, using the PBL with lecture method promotes deeper understanding of thermodynamics compared with using the conventional teaching method.

This result of current study concurs with the findings of numerous studies which assured the efficiency of the PBL with lecture method on the understanding of thermodynamics, for example Cheong (2008) pointed out that using the PBL approach alone and adopting it only as a teaching method is considered risky because of the complete shift from the teacher-centered learning in a conventional manner to the student-centered learning in PBL. PBL is a teaching method based on the principle of using problems, which are complex and ill-structured, leading to drastic changes in the learning approach (Cheong, 2008).

This finding also replicated the results obtained by Liceaga, Ballard and Skura (2011) who had earlier demonstrated the superiority of the PBL with lecture method over the PBL in bringing a positive influence on the learning process. Moreover, incorporating PBL into traditional method can be a useful tool to reinforce material covered in traditional lecture, and that will leave a positive impact on the learning process (Liceaga, Ballard & Skura, 2011).

Combination of both PBL and traditional approaches provid the most effective method for teaching and learning that leads to help students to understand thermodynamics better than their peers who are exposed to PBL alone without lecture method. In the context of medical students, according to Saalu, Abraham, and Aina (2010), "there should be an intelligent combination of using both the conventional and PBL approaches for teaching anatomy which may provide the most effective training for undergraduate medical student" (p. 197).

This study showed PBL with lecture method was superior over other methods in understanding of thermodynamics. There are several reasons for this result; for instance, students who came from traditional environment were not ready to study under PBL method because they need to have some skills such as group work skills and self-directed learning skills.

Conclusion

The findings of present study revealed the effectiveness of using the PBL with lecture method for enhancing the understanding of thermodynamics, better than other methods. In other words, using the PBL with lecture method enhances understanding of thermodynamics better than using the PBL alone and superior than using the conventional teaching method, among the physics undergraduates.

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