IIUM Journal of Educational Studies, 2:1 (2014) 56-66

Problem-Based Learning to Enhance Students' Understanding and Motivation for Learning Mechanical Science

Madihah Khalid[a], Hassan Rahman[b]

Abstract: This action research study sets out to investigate whether Problem-Based Learning (PBL) would enhance the technical students' level of conceptual understanding and motivation for learning the subject of mechanics. This action research study involved a single classroom from a technical college where the instructional intervention was implemented for about 4 weeks (a total of 8 lessons). Quantitative data was generated through the administration of Pre and Post-tests, rubrics and questionnaires, while qualitative data was collected through lesson observations and interviews. Based on the results obtained, the sample students in general were found to make the desired improvement in their level of conceptual understanding of Mechanics. Comparison made based on a phase-test with a parallel group also showed that the sample students performed better than their immediate counterparts. With PBL, the students felt that focusing authentic engineering problems made the subject more relevant to their interests while the collaborative learning approach in the PBL setting made students share ideas and support each other thus enabled them to grasp the conceptual understanding required.

Keywords: Technical Students, Problem-Based Learning, Conceptual Understanding, Mechanics, VTE in Brunei Darussalam

a Kulliyyah of Education, International Islamic University Malaysia, email: madihahkhalid@iium.edu.my
b Jefri Bolkiah College of Engineering, Ministry of Education, Brunei Darussalam, hassan.rahman@jbce.moe.edu.bn

Introduction

The introduction of academic subjects in the Vocational and Technical Education (VTE) curriculum is a new phenomenon and one such example of the academic subjects that has been included in the VTE curriculum in Brunei is Mechanical Science. Recent research suggests that technical students hold positive views about Mechanical Science and that both instructors and students recognize the importance of the subject in the National Diploma (ND) programme (Nurhanani & Baimba, 2006). However, the technical students' performance in a test that measured their conceptual understanding of the subject was very poor (Nurhanani & Baimba, 2006). One of the possible factors for the poor performance was the behaviorist teaching method employed by the instructors where it was revealed that the instructors emphasized more on numerical problem solving skills (procedural skills) than teaching for conceptual understanding (Nurhanani & Baimba, 2006). This fact motivates the researchers to carry out this study, in an attempt to improve students' understanding of Mechanical Science.

This study focuses on the instructional strategy in the teaching of Mechanics using the Constructivist approach through Problem-Based Learning (PBL). Subsequently, the effects that this teaching method has on the students' performance, level of conceptual understanding of the topic as well as the students' motivation were examined.

Background to the study

The implicit learning theory underpinning VTE since the Vocational Education Act in 1917 has been behaviorism (Dolittle & Camp, 1999). To this day, behaviorism remains the primary basis in learning theory for both the curriculum and pedagogy of VTE. However, many researchers advocated for a new look at the theoretical framework for VTE and there is a move towards accepting learning theory grounded in constructivism to guide the pedagogy in VTE (Doty & Weismann, 1984).

Constructivism is a theory based on the idea that learners construct their own knowledge from experience (Fosnot, 1996). Dolittle and Camp (1999) affirmed that constructivism acknowledges the learner's active role in the personal creation of knowledge, the importance of experience in this knowledge creation process and the realization that the knowledge created will vary in its degree of validity as an accurate representation of reality. One form of constructivist pedagogical approach is Problem-based Learning (PBL). It is an educational strategy where learning is driven by a problem. The problem could be a challenge or a description of a difficulty, a curious outcome or an unexpected happening. It could also be an incident where there are interesting elements or an episode or happenings that either requires a solution or some explanation (O'Grady & Alwis, 2002).

In general, PBL is a constructivist, student-centered instructional strategy in which students collaboratively solve problems and reflect on their experiences. Hmelo-Silver (2004) in his study found that the curricular design of PBL is suited to helping students become active learners because it situates learning in real-world problems and makes students responsible for their learning. Students who went through PBL demonstrated attitudes and actions expected from independent, academically effective learners, utilizing meta-cognition, intrinsic motivation and strategic planning (Sungur & Tekkaya, 2006).

Methodology

Study Sample

The technical school selected for this study was one of the VTE institutions in Brunei. The college offers programmes at the ND level in diverse fields such as Computer Engineering, Electrical and Electronic Engineering, Mechanical and Manufacturing Engineering, Plant Engineering and Building Services Engineering. As for the students sampling for this study, a group of 34 students constituted the sample.

Research Instruments and Data Collection

Quantitative data obtained in the study was through the administration of pre-test and post-test as well as questionnaires. The pre-test which constituted 20 multiple choice questions (MCQ) was administered to the students before any instructional intervention was made to determine students' pre-existing knowledge and for the purpose of comparison later. In contrast, the post-test which also consisted of 20 MCQ was developed parallel with the pre-test and was administered to the students after all the intervention had been completed. The students completed both tests in one hour. The gap between the administration of the pre- and post-test was about two months. Meanwhile, questionnaires were distributed to the students to examine their perception of the PBL lessons that they had experienced for about one month. The questionnaire was made up of two categories; Problem-Based aspects and Collaborative work aspects consisting 28 statements and were administered immediately after the students had completed the post test. An example of a positive statement from the Problem-based category was "*I understood the topic in the Mechanical Science subject better when I learnt through PBL*" whereas a negative statement from the Collaborative work category was "*For me, discussing the material in my Mechanical Science class with my classmates is a waste of time*". The students spent twenty minutes to complete the questionnaire.

The qualitative data obtained in the study was through lesson observations and interviews. Two rubrics were used to record the teaching and learning observations in order to systematically capture how the students were coping with the instructional intervention made (Observation of Learning rubric and Team Presentation rubric). Students' work was also collected to check their thinking and understanding of the problems. Finally, interviews were conducted after the researchers had completed all of the lessons. Six students were selected according to their ability (identified from the pre and post-tests results as well as students' performance in class) - two Low achievers, two Medium achievers and two High achievers. Interview questions were semi-structured and all students were interviewed for a duration of ten minutes each.

Validity of obtained data was ensured by aligning to the quality criteria of the methods of data collected. Tests and questionnaire reliability were determined by the Cronbach alphas of 0.71 and 0.78 (0.72 for problem-based scale and 0.76 for the collaboration scale) respectively, which are considered acceptable according to Nunnally (1978). The qualitative data satisfies the criteria of prolonged engagement, peer debriefing, member checks, triangulation, and progressive subjectivity (Lincoln & Guba, 1985).

Design and Techniques of Data Analysis

Students' responses to the questionnaire were coded as follows: positive item responses of Strongly Agree (SA), Agree (A), Disagree (D) and Strongly Disagree (SD) were scored 4,3,2,1 respectively. Negative item responses of SA, A, D, SD were scored 1,2,3,4 respectively while omitted answers were not scored. The Statistical Package for Social Science (SPSS) software version 18 was used to analyze the responses to the questionnaire using descriptive and inferential statistics. The pre- and post-tests were marked, scored, averaged and compared to look for any significant difference in the students' performance. Paired t-test was used to determine the significance. The institution also happened to conduct Phase Tests after the completion of some topics on a regular basis. This test is a standardized test for all students who had learnt the said topics. This gave the researchers an opportunity to compare the result of another group of students with similar traits to the sample group. An independent sample t-test was performed to compare their results. Meanwhile, the interviews were transcribed and examined for any particular emerging themes or regular patterns. This information was used to support or contradict those evidences provided through the questionnaire and the pre- and post-tests.

Results and discussion

Effects of the Instructional Intervention on Students' Performance

When the mean scores from both the pre- and post-tests were compared to each other, it can be observed that there was improvement made by the students whereby there is a positive mean score difference of 1.63 (see Table 1). This slight improvement is deemed acceptable, particularly considering that there was a time constraint in carrying out the instructional intervention. Four weeks could be considered relatively short, although the eight two-hour lessons satisfied the prolonged engagement criteria. Hence this factor could be one of the reasons why the improvement was not great or drastic.

Table 1. Mean Values, Mean Differences, Standard Deviations, Standard Deviation Differences, r-value, t-value and p value for the Pre Test and Post Test Scores (N = 34)

	Mean	Mean Difference	Standard Deviation (SD)	SD Difference	t	Sig. (p)	r	Sig. (p)
Post-test	10.54	1.63	2.41	0.46	3.10	0.005	0.54	0.006
Pre test	8.92		2.87					

Nevertheless, when a paired sample t-test was performed to the results from the pre- and post-tests, a positive t-value of 3.10 was achieved and was statistically significant at $p › 0.01$ (refer Table 1). This implies that the results or rather the improvements made by the students in the post-test are not just due to chance. In fact, it can be said that there has been improvements made by the students. As a result, it would appear that the method of teaching employed for this particular group of students from this particular technical school has helped the students enhance their level of conceptual understanding of Mechanics. In addition to that, having computed the Pearson's correlation coefficient, *r* for both the pre and post-test scores, the coefficient of 0.54 obtained implies that in general, most of the students have made an improvement even though there were a few exceptions (see Table 1). These exceptions are expected gain in test scores. This result was further supported by the observation checklist (rubric) which showed an increase in particular aspects of learning such as enhanced 'Team Presentation' and 'Learning Features'.

To further justify the improvements made, a comparison was made with another group of students who took the same phase test (phase tests are conducted in the institution regularly for students learning the same topic but with different teachers and was set independently of this study) on the same topic. The comparison group consisted of students of similar social and academic background with the students learning the topic through PBL. It was found that the sample students performed better than their counterparts with a percentage mean of 50.74 as compared to 32.95 (see Table 2).

Table 2. Percentage Mean Values, Percentage Standard Deviations, t-value and p value of the Phase Test Scores for Both the Experimental and the Comparison Group (N=34)

	Percent-age Mean	Percentage Standard Deviation (SD)	t	Sig. (p)
Experimental Group	50.74	14.06	5.10	0.0001
Comparison group	32.95	9.72		

Using independent sample t-test, it was found that a positive t-value of 5.10 was achieved and the difference in score was extremely significant at $p < 0.01$. This suggests that the experimental group did better in the phase test than the comparison group.

Generally, the students reported that learning through the PBL approach was difficult and they reasoned this to be due to the nature of the problems given. This was anticipated as the students were not exposed to solving real-life problems similar to those presented in the PBL lessons. Instead these students were used to solving textbook problems which were very often set in an abstract context rather than in the context of their daily life experiences. Furthermore, since similar examples were already solved by the teachers teaching them, they could figure out the solution by just following similar procedures or workings made by the teacher. However, the students did state that they enjoyed learning the Mechanical Science subject through PBL. They attributed this to the fact that solving the problems on their own has given them the opportunities to engage themselves in their learning and to develop their own understanding of the concepts based on their experiences. This necessity for engaged learning is crucial as the new global, fast changing economy requires knowledgeable workers who can synthesize and evaluate new information, think critically and solve problems (Fredricks et al., 2004).

As for the collaborative work aspects that were integrated in the PBL approach, the students reported that working in groups with their classmates was enjoyable as they can learn and assist one other through the sharing of ideas. This claim coincides with the research from Effandi (2005) who affirmed that cooperative learning creates excellent opportunities for students to engage in problem solving with the help of their group members. Despite that, some students did point out that they would only benefit from learning in groups if all of the group members were cooperative and willing to share the responsibilities of working in groups. This claim is mirrored in a study conducted by Ong and Yearn (2000) where they stated that teachers should teach the missing skills, review and reinforce the skills that students need in order to work in groups effectively.

Effects of the Instructional Intervention on Students' Conceptual Understanding of Mechanics

As for the students' conceptual understanding, generally the students felt that PBL had helped them to understand the topics that had been taught. One student commented that she understood the topics taught better as a result of solving the problems given on her own rather than waiting for the teacher to solve the problems for her and then listen to the teacher's explanation in front of the class. This positive feedback is further backed up by the claim that self-directed learning makes learners become aware of learning as a process of conceptual refinement where they construct their own conceptualization and solution to problems (Sungur & Tekkaya, 2006). Among those interviewed and surveyed, some students attributed their accomplishment in acquiring the required conceptual understanding to the collaborative work that was integrated in the PBL setting. These students reported that when they were having difficulties, they would gain the necessary understanding with the assistance of their class mates. Davis (1993) backed up this claim by asserting that students who work in groups develop an increased ability to solve problems and evidence greater understanding of the material.

Table 3. Total Mean Values and Total Standard Deviations of Items from the Questionnaire

Item	Total Mean	Total Standard Deviation (SD)
Problem-Based aspects	2.99	0.59
Col aborative work aspects	3.26	0.54

With the element of collaborative work present in the PBL approach, most if not all of the students felt that, collaborative learning did help them a lot in further grasping the understanding of the topics taught as per reflected in the high total mean of 3.26 (refer Table 3). The mean score of 3.26 also showed that the students mostly agreed to strongly agree that the collaborative learning aspects in the classroom made their learning for Mechanical Science better. This was evident in one of the lessons carried out when no group work was conducted on purpose. The outcome was that most of the students struggled to even get started with the problem solving on their own. This was in contrast to when they were eventually asked to work in groups where they then managed to solve the given problem with less supervision. This supports the idea that these students gained the necessary understanding by working and learning effectively in a group. This claim is further supported by a study conducted by Heller, Keith and Anderson (1992) where they concluded that better problem solutions emerged through collaboration than were achieved by individuals working alone. It can also be seen from Table 3 that the total mean to problem-based aspects is 2.99. This suggests that students generally agreed to most of the positive statements that characterized PBL.

Other Findings As A Result of the Intervention

One of the students who suffered an adverse effect from the intervention is a Medium achiever student whereby she commented that she did not enjoy the PBL experience. She compared it with her past experiences where she mentioned that her previous teacher would first "explain" to them the subject matter before giving any problems to be solved. In other words, she expects information to be fed first by the teacher rather than her trying to unfold the problems given and to work it out from there. This response was expected from the student since she has not experienced this kind of learning before. She considered "teaching" and explanation from the teacher before she could attempt any question as what a normal classroom is usually about.

However, she remarked that learning collaboratively with her friends was an enjoyable experience and that working in groups gave her the opportunity to share ideas and assist others in solving the problems given. Ironically, one of the students whose performance dropped in the tests happened to be one of the High achiever students. But when asked about her views on her PBL experience, she stated that she enjoyed the PBL lesson because she understands better as a result of solving and working out the problems on her own rather than the teacher instructing and explaining in front of the class.

Conclusion

This study, though limited in scope, has, however, produced some interesting results. The sample students, in general, had made the desired improvement in terms of test scores and attitude. Thus with such favorable effects, the possibility of this applied instructional intervention being implemented in the VTE context, is very promising indeed. The students felt that the PBL approach has provided them with learning opportunities which they would not have had in a traditional classroom setting. Nonetheless, the students did feel that learning through PBL was difficult at first as they were not used to this method of teaching and learning. However, as a result, they became more responsible towards their own learning in a sense that they became self-directed.

References

Davis, B. (1993). Tools for Teaching. San Francisco: Jossey-Bass.

Dolittle, P. & Camp, W. (1999). Constructivism: The Career and Technical Education Perspective. *Journal of Vocational and Technical Education*, 16 (1), 23-46.

Doty, C. & Weissman. (1984). Vocational Education Theory. *Journal of Vocational and Technical Education*, 1 (1), 5-12.

Effandi, Z. (2005). *Asas Pembelajaran Koperatif Dalam Matematik*. Shah Alam: Karisma Publications Sdh Bhd.

Fosnot, C. (1996). *Constructivism: Theory, Perspective and Practice*. New York: Teachers College Press.

Fredricks, J., Blumenfeld, P. & Paris, A. (2004). School Engagement: Potential of the concept. *Review of Educational Research*, 74 (1), 59-109.

Heller, P., Keith, R. & Anderson, S. (1992). Teaching Problem Solving Through Cooperative Grouping. Part 1: Group versus Individual Problem Solving. *American Journal of Physics*, 60 (7), 627-636.

Hmelo-Silver, C. (2004). Problem Based Learning: What and How Do Students Learn? *Educational Psychology Review,* 16 (3), 235-266.

Lincoln, Y & Guba, E. (1985). *Naturalistic Inquiry Sage*, Beverly Hills, CA Nunnally, J. C. (1978). *Psychometric theory,* New York: McGraw-Hill.

NurHanani, K. & Baimba, A. (2006). Technical Students' Views on, and Conceptual Understanding of Mechanics. Journal of Applied Research in Education, 10, 163-173. O' Grady, G & Alwis, W. (2002). One Day, One Problem: PBL at Republic Polytechnic. 4th Asia Pacific Conference in PBL. Thailand.

Ong, E. T. & Yearn, K. P. (2000). The Teaching of Social Skills in Cooperative Learning. Classroom Teacher, 5 (2), 41-49.

Sungur, S. & Tekkaya, C. (2006). Effects of Problem Based Learning and Traditional Instruction on Self Regulated Learning. *Journal of Educational Research,* 99 (5), 307-317.