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Formative and Summative Evaluations in Learning Physics: Do They Complement Each Other?

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Abstract

A correlational study was conducted to analyse the relationship between students' performance in problem-based learning (PBL) and final exam scores with two student cohorts. This study focused on PBL as a teaching strategy and how it related to the students' achievement in the final exam of a physics course. Exam reliability was assessed by Cronbach's alpha, and values were obtained ranging from .71 to .83. Correlation between students' scores in PBL and the final exam was analysed using Pearson's correlation coefficient. Statistical significant was shown only for semester 2 in Cohort A. For Cohort A semester 1 and both semesters for Cohort B, the correlations were not significant. The corresponding highest Pearson correlation coefficient was .19, which was only for Cohort A semester 2. Coefficients of determination showed that PBL accounted for about 0 to 3.7% of the variance in students' final exam scores. In all semesters for both cohorts, the difference between final exam scores and PBL scores was significantly higher in the upper quartile of students' scores, and lower in the lower quartile of students' scores. Thus, this study showed that PBL can be implemented as one of the teaching strategies to improve some students' academic achievement.

Keywords: *Physics, teaching strategy, problem-based learning, assessment, achievement*

Introduction

Teaching science effectively in schools, especially physics, is a challenge for educators, and has been of great concern in Malaysian educational institutes for a long period of time (Halim et al., 2012). Several researchers have identified the weaknesses in Malaysia's teaching and learning methods. The main problem with traditional methods of teaching is that students tend to memorize problem-solving strategies without understanding the concept. This is a consequence of the method of teaching that emphasizes problem-solving rather than conceptual understanding (Mazur, 1999). Since Malaysia's education system has a tendency to be examination-oriented (Kirkpatrick & Zang, 2011), it leads to a poor mastery of core and generic skills in students' learning (Goh & Ali, 2014). The goal of learning science in the 21st century, as noted by the South Africans, is to educate students to understand concepts, develop process skills, and develop thinking skills for knowledge transfer (Department of Education, 2011). Pang (2011) stated that one of the key strategies for building an integrated human workforce is to restructure the education system to enhance students' performance. Hence, educators need more effective teaching methods to provide motivation for courses, help students with difficulties, (EL-Shaer & Gaber, 2014), and be relevant for learners in a Science, Technology, Engineering and Math (STEM) community. According to Pedaste et al. (2015), students can engage with real-world applications of science and mathematical principles, by integrating technology into mathematics and science courses. Learning activities should focus on activating students' creativity and critical thinking skills, rather than be restricted to rote learning (Goh & Ali, 2014).

Several researchers have explored the benefits of problem-based learning (PBL) and how it affects the performance of students in learning science. As an educational method, PBL assists learners in applying scientific knowledge to real-life situations using an open inquiry technique (Ketpichainarong et al., 2010). This is unlike the conventional passive teaching method, which does not encourage problem-solving and the development of cognitive skills (Ronis, 2008). Students who are exposed to PBL can transfer their skills and knowledge into real-life situations (Hoffman & Ritchie, 1997). Sungur

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and Tekkaya (2006) believed that PBL enabled students to improve self-regulatory skills, and thus enhance their academic performance. PBL as a teaching method encourages students to understand the process of information searching related to a problem, thus enhancing their thinking capability (Aidoo et al., 2016). The teacher only assists the students throughout the process of learning, while the students take charge of their own learning to find a solution (Ngeow & Kong, 2001). Cockrell et al. (2000) agreed that student's perception of PBL instruction had increased, as it allowed them to foster knowledge transfer. PBL is more effective compared to other pedagogical methods, for it facilitates students' problem-solving and critical thinking skills since the learning theory can be applied in practice (Cooke & Moyle, 2002). Tretten and Zachariou (1995) stated that PBL allowed students to improve their ability to think critically after analysing a problem. This is due to their exposure to positive learning attitudes and the development of problem-solving skills (Aidoo et al., 2016).

However, several studies have highlighted some challenges in the implementation of PBL in science learning. Lockheed and Verspoor (1991) revealed that teaching science through the use of PBL appears to have some challenges, such as the lack of teaching aids, the lack of learning materials, the large size of classes, teachers' attitudes regarding science, and teachers' pedagogical skills. Ageorges et al. (2014) added that the limited number of teaching staff, the large number of students, and the economic constraints of educational institutions lead to difficulties in developing the PBL methodology. Besides, Bakaç (2014) stated that the most difficult process encountered in the PBL approach was to prepare suitable scenarios for the subject's learning gains. Preparing questions for evaluating the achievement of students in PBL becomes complicated, and assessment must be well-planned in advance (Ertmer et al., 2009). Energy and time invested in preparing successful PBL programs that promote learning and arouse students' interest may discourage lecturers (Barber et al., 2015). Another major challenge in the implementation of PBL was the negative reaction of students to PBL (Ageorges et al., 2014). Also, students may not have the ability to carry out the inquiry process effectively, and thus become demotivated during the learning approach (Edelson et al., 1999).

Multiple studies have been completed in the field of medical enquiry, where PBL was introduced as a hybrid curriculum. Although PBL was first introduced in the field of engineering, research concerning the effectiveness of PBL for engineering students or those taking physics remains rather limited. To improve students' performance in physics, lecturers should use a more engaging teaching strategy. PBL is one of the strategic teaching methods.

Methodology

Research Approach

The present researchers sought to provide insights into the ability of lecturers to distinguish between excellent and poor students by using the final examination performance as a basis of comparison with PBL. In PBL, facilitators were instructed to evaluate students' knowledge and their ability to integrate knowledge, regardless of group skills. This approach was adopted, for at the end of each semester, the aim of the study was to produce a component of the overall assessment that represented student learning irrespective of their performance on exams.

A correlational research approach was used in this study to analyse the relationship between students' performance in PBL and final exam scores. This involved the use of two student cohorts studying physics. The curriculum examined encompassed two semesters in a one-year foundational program. During the first semester, the physics course focused on the study of motion in a body or a system, and in the second semester, the course contained electromagnetism, which included both electricity and magnetism. The curriculum was designed to cover all learning objectives of the course. In grading students' performance in both PBL and the final examination, the lecturers used the answer schemes and rubrics provided to guide their evaluation. If students' final grades produced a significant correlation with their scores in PBL, the PBL assessment would be maintained for the next cohort. It was expected that PBL as a teaching strategy could help improve students' learning in the physics course. The null hypothesis adopted, hence, was that students' scores in PBL would not be correlated with students' exam scores.

Participants

The study employed an institutional database as the source of data. Use of this database for research purposes was approved by the institution's management. The data were gathered from pre-university physics students, with 385 students in Cohort A and 308 students in Cohort B as participants.

PBL Scoring Method

In PBL, facilitators were asked to assign a grade to the small group for students' performance. Performance includes multiple criteria, such as preparation, the ability to use and explain scientific terms and information, and the integration of scientific knowledge in problem solving. Assessment also included group interaction skills, such as cooperation, group dynamics management skills, oral presentation skills, and professional attitude. This curriculum structure was crucial to decide on the inclusion of evaluation of knowledge in the PBL component. In PBL, facilitators were instructed to evaluate students' knowledge and ability to integrate their knowledge, regardless of group skills. This approach was adopted because at the end of each semester, the study's aim was to produce a component of the overall assessment that represented students' learning irrespective of their performance on exams.

Data Collection and Analysis Method

This study was a correlational quantitative study that utilised two variables of interest: the students' scores in PBL and the final exam scores for both Cohorts A and B. The reliability analysis of the final exam was examined by computing Cronbach's alpha. Cronbach's alpha is a measure used to evaluate a set of scale or test items' reliability, or internal consistency. The reliability of any measurement refers to the extent to which a concept is consistently measured, and Cronbach's alpha is one way to measure the strength of this consistency.

The relationship between the scores in PBL and final exam was analysed by Pearson's correlation coefficient, which was used to estimate and test the correlation in both student cohorts. The Pearson coefficient of correlation, r, is a measure to determine the relationship between two quantitative variables and the degree to which they coincide with each other. In this study, the strategy adopted was that if there was no significant relationship between students' PBL scores and final examination scores, then segmentation of the cohorts into smaller groups would be undertaken. An independent t-test also was used to compare the differences in students' performance in PBL and the top and bottom quartiles of the final exam grades. Analyses were performed using the SPSS software system.

Results

The reliability analysis was carried out primarily by calculating Cronbach's alpha coefficients for the final exam. Results are shown in Table 1. They demonstrate that the mean alpha for the final exam was $.79 \pm .06$, and ranged from .71 to .83. Consequently, the final exam scores for both cohorts had Cronbach's alpha levels which showed that they were reliable.

Table 1. Examination Reliability

Cohort	Semester	Cronbach's Alpha for Final Exam
A	1	.71
	2	.83
B	1	.79
	2	.83

Mean final exam scores and PBL scores for both cohorts are shown in Table 2, and Pearson's correlation coefficients for both cohorts are shown in Table 3. The findings indicate that the correlation was positive, which means that if the PBL scores increase, the final exam scores also will increase. The correlation was statistically significant only for Cohort A semester 2. For Cohort A semester 1 and Cohort B semesters 1 and 2, the correlations were not significant. The corresponding significant Pearson's correlation coefficient was .192, which was only for Cohort A semester 2. Hence, the null hypothesis, which stated that there was no correlation between PBL score and final examination score, was rejected only for Cohort A semester 2.

The *p*-value of the correlation was used to test whether the correlation is different from 0. Thus, the finding shows that the actual magnitude of the correlations for both cohorts was low since they were below .30. Furthermore, the coefficients of determination ranged from 0 to .037 for all semesters. Hence, students' scores in PBL would account for about 0 to 3.7% of the variance observed in the final examination scores.

Table 2. Final Exam Scores and PBL Scores for Students in All Semesters

Cohort	Semester	Final Exam Score Mean ± *SD**	PBL Score Mean ± *SD**
A	1	22.37 ± 6.74	8.27 ± 0.89
	2	30.40 ± 8.31	8.45 ± 0.80
B	1	25.65 ± 6.70	8.27 ± 0.65
	2	30.79 ± 8.82	8.69 ± 0.57

**SD* = Standard Deviation

Table 3. Pearson Correlation Coefficients for Final Exam Scores and PBL Scores

Cohort	Semester	Correlation Coefficient	*p* Value
A	1	.087	.089
	2	.192	.000**
B	1	.066	.245
	2	-.093	.103

**Significant at .01 level

Descriptive plots, illustrated in Figure 1, show positive correlations between final exam scores and PBL scores for semesters 1 and 2 for Cohort A. The slope of the line in semester 2 was greater than that shown for semester 1.

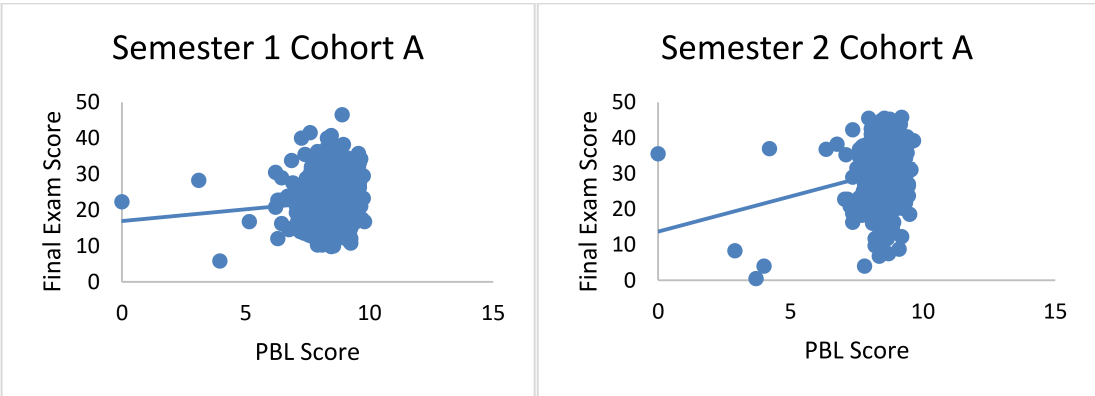

Figure 1. Correlation between Final Exam Scores and PBL Scores for Cohort A

A similar analysis for Cohort B showed a positive correlation in the first semester and a negative correlation in the second semester. However, the positive correlation for both Cohorts over three semesters (Cohort A: semesters 1 and 2 and Cohort B: semester 1) was approaching a zero value, which means that the correlation was weak. However, the scatterplots suggested another possibility, namely, that that there might be a stronger correlation between final exam and PBL scores for higher-scoring students than for lower-scoring students. This possibility was investigated further by sub-dividing the data by quartiles and completing further correlation analysis.

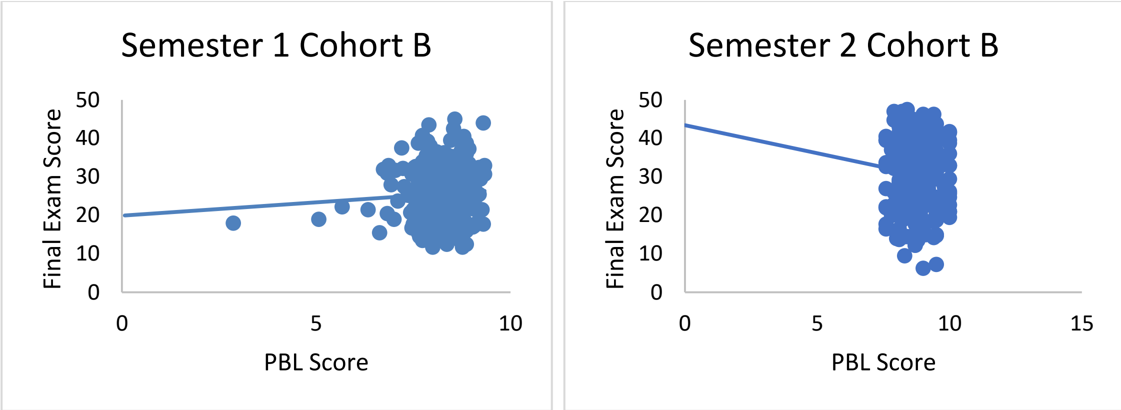

Figure 2. Correlation between Final Exam Score and PBL Score for Cohort B

The differences between final exam scores and PBL scores in the extreme quartiles were promising, and the data obtained are shown in Table 4. In all semesters for both cohorts, the mean difference was significantly higher for the upper quartile of students' scores than for the lower quartile of students' scores.

Table 4. Difference between Final Exam Scores of Students in the Top and Bottom Quartiles of PBL Exam Performance

Cohort	Semester	Quartile	Mean Final Exam Score $\pm$ *SD*	*p* value
A	1	Top	22.32 $\pm$ 3.91	< .000
		Bottom	7.11 $\pm$ 2.09	< .000
	2	Top	31.03 $\pm$ 2.60	< .000
		Bottom	11.73 $\pm$ 5.62	< .000
B	1	Top	25.48 $\pm$ 3.39	< .000
		Bottom	9.89 $\pm$ 2.27	< .000
	2	Top	32.14 $\pm$ 2.59	< .000
		Bottom	10.83 $\pm$ 4.16	< .000

Note. The top quartile was defined as the final exam grade equal to or greater than the top 25% of final exam grades. The bottom quartile was defined as the final exam grade less than or equal to the bottom 25% of final exam grades.

Discussion

Evaluating students' knowledge based on PBL assessment is a challenge for physics lecturers. Based on the present research findings, it was shown that PBL assessment gave a positive correlation with students' grades in the final examination for only one semester and one cohort. The correlations obtained for the other semesters were not significant. The analysis for one semester (Cohort B, semester 2) returned a negative correlation. This means that findings from the present study were not strongly aligned with several previous studies which indicated that the PBL method was much more effective in teaching physics than the traditional method. For example, Argaw et al. (2017) showed that a PBL strategy was superior to a traditional approach when adopted among senior students in Ethiopia. A similar result was shown in a study conducted among freshmen university students in a Turkish university. It was shown that teaching physics using the PBL method compared to conventional method was more effective in enhancing course success than the traditional approach using rehearsal and memorization, with a difference significant at the 5% level (Gamze et al., 2013). Similar outcomes were found in a study conducted in Iraq among college students. Through using a PBL approach, the students were better prepared to be more autonomous in their ability to define a problem, decide on information relevant to resolving the problem, and then develop an approach best suited to finding a solution (Aziz et al., 2014).

Changed attitudes was also an important outcome. Selçuk (2010) agreed with previous findings that students who were trained using the PBL method, or a deep learning approach, developed a better attitude towards learning physics compared with students who were taught by a surface, memorization approach. Such an approach also improved their ability to apply and integrate knowledge, and to discuss problems intelligently while at the same time improving student interest in the subject matter (Dolmans et al., 2016).

The significant correlation noted in semester 2 for Cohort A involving the whole group ($p < .01$) may be have been due to the students' interest towards the subject of electromagnetism in that cohort. The low determination correlation coefficients for all semesters indicated that the factors which accounted for students' scores in PBL and actual student performance are slightly overlapping. In PBL assessment, the scores of students may reflect the bond that develops in group sessions between the facilitator and students through frequent contact. The facilitator's tendency to overrate students, particularly students in the lower quartile, agreed with a previous study, where it was found that facilitators are unwilling to give unsatisfactory grades (Couto, et al., 2019). Since students have access to their written notes and texts during PBL group discussion sessions, facilitators may find it difficult to judge students' ability to retain this information until the final examination, when notes and texts are not permitted. Despite all this, the mean difference between final exam scores and PBL scores showed that the upper quartile of students' scores was significantly higher, and the lower quartile of students' scores was significantly lower. Thus, this strongly indicated that a significant relationship existed between students' PBL scores and final examination scores in the extreme quartiles.

Although the result in one semester (Cohort A, semester 2) was significantly positive, the overall findings of this study do not seem to strongly agree with many previous studies. This may be due partly to design difficulties that were faced by both lecturers and students during PBL assessment. As the regular teaching program continued, finding small classrooms and staff who had mastered the PBL method was challenging. In addition to that, the PBL students asked the lecturers for more guidance, since they were uncertain how much study to do and what information was relevant to the scenario.

Conclusion and Limitations

It was concluded that PBL can be implemented as one alternative method to improve students' academic achievement, and further study on the correlation was recommended for the next cohort. This study revealed that, under some circumstances, students' final grades may correlate well with their scores in PBL. Thus, it is necessary to use PBL for the next cohort so as to further study how PBL may be used most effectively to assist in improving students' learning in physics courses. PBL as a teaching and learning strategy may enhance students' performance in physics if relevant issues such as the adequacy of teaching aids, the number of large classes, and the lecturers' teaching experience and skills can be addressed. Further research needs to be undertaken to enrich and provide students with long-term benefits of learning physics, as well as transforming the Malaysian education system so that it is aligned with the vision and mission of 21st century learning.

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