

# The effectiveness of problem-based learning approach in science subject

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## ABSTRACT

The study was conducted to investigate the effectiveness of problem-based learning (PBL) on the achievements of Form one science students in Klang. Malaysia's low ranking in scientific knowledge, as highlighted by the Programme for International Student Assessment (PISA), underscores the need for innovative teaching methods. Therefore, this study investigates the impact of PBL intervention on science subjects among 60 Form one students consisting of 30 treatment group and 30 control group students. The research instruments used were pre-test and post-test designed by the researcher. The pre-test was conducted using both treatment and control group students. The treatment group was exposed to PBL intervention for eight weeks before post-tests were given to both groups. Data was analyzed by using the independent t-test and paired t-test for pre-test and post-test. The research findings showed that the treatment group demonstrated significantly higher post-test scores than the control group. The findings suggest that the PBL approach positively impacts students' learning achievements. Therefore, the study supports the adoption of PBL to enhance science education among Form one students.

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## 1. INTRODUCTION

Science is a core subject that primary and secondary school students must take alongside other subjects integral to their educational development. According to the Ministry of Education, Malaysia is ranked below average in two consecutive Programme for International Student Assessment (PISA) exams which enlightened many people about the quality of the national education system in Malaysia despite the illustrated improvements [1]. These rankings suggest that while there have been improvements, significant gaps remain, particularly among science educators and urgent need to adopt creative and innovative teaching methods to enhance students' performance in science subjects [2]. However, many teachers still prefer conventional or lecture-based teaching methods, which can limit students' engagement and make them passive learners in learning science and unable to explore scientific concepts deeply [3]. Consequently, there is a need for pedagogical advancements that not only engage students but also develop their critical thinking and problem-solving skills.

To address this challenge, the Ministry of Education has considered the constructivist theory, which develops the cognitive level of students arouses two-way interaction in the classroom, and positions students as active participants in their learning process [4]. Despite, this empirical evidence on the effectiveness of PBL specifically in Malaysian classrooms, where passive learning remains a barrier. This research was

conducted to address this gap by finding out the impact of problem-based learning (PBL) in science subjects among Form one students in Klang compared to traditional methods. This research implements the PBL approach in science classrooms, hypothesizing that it will enhance student engagement and achievement by fostering active, self-directed learning.

PBL encourages students to be independent in learning science, while teachers act as guides [5]. It helps students to apply knowledge in real-life situations and discuss to find solutions [6]. In addition, students develop critical, creative, and analytical thinking skills [7]. Therefore, this study could address the current challenges in science education, specifically in Malaysia, such as underperformance in PISA rankings and the prevalence of passive learning due to traditional teaching methods [8]. The research seeks to answer the following question, what is the effectiveness of PBL on the academic achievement of Form one science students compared to traditional teaching methods? The motivation behind this research was to investigate whether PBL could serve as an effective tool to address the limitations of traditional methods and improve science learning outcomes among Form one students in Klang. Hence, the PBL method was implemented in Form one science classrooms in Klang and the impact on students' learning outcomes compared to traditional methods was measured.

## 2. METHOD

### 2.1. Research design

A quasi-experimental approach with pre-test and post-test was used to compare the effectiveness of PBL and conventional teaching methods on students' science achievement. Non-equivalent two groups of students were selected, with one group receiving PBL and the other received traditional instruction [9]. The PBL lesson plans were designed by researchers and applied during science periods via online classes for eight weeks. While conducting a quasi-experiment, a few factors have to be taken into consideration based on Chua *et al.* [10] to have validity in the experiment. Thus, both treatment PBL and control (conventional learning) groups of students were used for this research [11]. The quantitative method was employed to analyze numerical data from test scores, using t-tests to evaluate differences between the groups. Table 1 shows the variables involved in this research.

Table 1. Variable table

Group	Independent variable	Dependent variable
Experimental	PBL	Learning achievement in science
Control	Conventional learning method	Learning achievement in science

### 2.2. Design of PBL lessons

The topics for PBL intervention were based on the Form one science syllabus in Malaysia specifically from topic 8 (light and optic) and topic 9 (earth). The researchers developed PBL lessons and implemented them during online classes with students. The PBL format can be integrated with scenarios, events, video, audio, and photographs [12]. Figure 1 shows a sample of PBL problem used in the lesson.

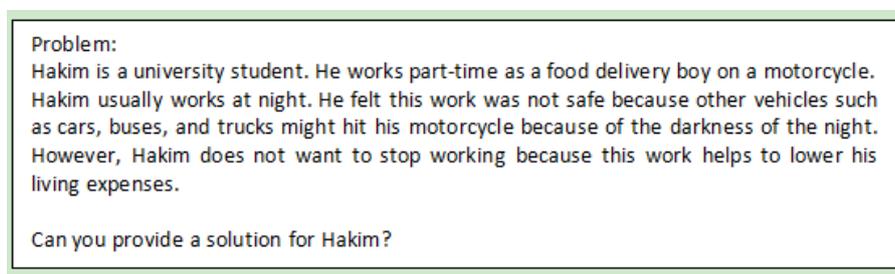


Figure 1. PBL problem

### 2.3. Sampling methods (types of sampling)

The population for this research were students from a school located in Klang, Selangor, Malaysia. The students involved were in two classes from Form one taking science subjects. This group of students was the existing group taking science subjects. One of the classes was the experimental group that underwent

PBL. Another group acted as the control group and underwent a traditional method of teaching process. Both the experimental group and control group consisted of 30 students. Purposive sampling was used in the research since the research was conducted with the existing group of Form one students taking science subjects in Klang. Future studies could replicate similar research using a larger number of teachers from various school types, school sizes, and other demographics in Malaysia to understand the nature of this relationship, as this study only focused on one secondary school in Klang. The sample size of 60 students from two classes is adequate because it represents the entirety of the accessible population under investigation. According to Lakens [11], when data is collected from the entire population or a near-complete subset, the sample size justification becomes straightforward, as the finite population correction factor ensures reduced variance, making confidence intervals narrower and more precise.

#### 2.4. Research instrument

Pre-test and post-test question was used as instruments in this research. The pre-test and post-test were given to answer the first research question which is to examine the effectiveness of PBL in students learning achievements. These questions were developed by the researcher during the internship. Both pre-test and post-test are not similar but the level of difficulty was the same. The pre-test and post-test were given to students in Google Form Quiz. In both experiment and control groups, students were required to complete the pre-test and post-test.

#### 2.5. Data collection procedures

The research begins with the determination of treatment and control group students. Pre-test questions were designed and verified by two lecturers. After the verification of pre-test questions, the tests were given out to all treatment and control group students in the form of a Google Form Quiz. PBL lesson was conducted for eight weeks using treatment group students, while the control group students were exposed to conventional teaching methods. After the PBL intervention, post-test questions were designed and verified before being given to all treatment and control group students.

#### 2.6. Data analysis procedures

The data was analyzed using SPSS software version 26.0 for both instruments. For pre-test and post-test, the types of analysis are independent t-tests and paired t-tests to compare the scores between two groups of students. The questionnaire set was analyzed using mean and standard deviation to identify which set items students prefer more in PBL. Both data collected are quantitative data, hence only one procedure is involved in the thesis.

### 3. RESULTS AND DISCUSSION

#### 3.1. Effectiveness of PBL on students' learning achievements

The research involves two groups of students namely treatment and control groups comprising of Form one students taking science subjects. For this research, 60 participants responded to pre-test and post-test, 30 from the treatment group and 30 from the control group. Comparison marks of treatment and control groups students for pre- and post-tests are demonstrated in Tables 2 and 3. Both pre- and post-tests consist of 30 objective questions each carrying one mark. The test was administrated and marked out of 30. The difference in score is calculated by simply deducting the post-test score from the pre-test score.

Table 2. Marks of treatment group test

No.	Respondent	Pre-test	Post-test	Difference	No.	Respondent	Pre-test	Post-test	Difference
1	1	21	22	1	16	16	10	20	10
2	2	8	11	3	17	17	9	24	15
3	3	21	21	0	18	18	6	11	5
4	4	5	11	6	19	19	14	17	3
5	5	5	13	8	20	20	7	20	13
6	6	9	15	6	21	21	9	16	7
7	7	6	8	2	22	22	6	17	11
8	8	9	17	8	23	23	6	8	2
9	9	7	17	10	24	24	7	5	-2
10	10	8	28	20	25	25	10	30	20
11	11	19	27	8	26	26	6	10	4
12	12	12	21	9	27	27	4	5	1
13	13	12	27	15	28	28	9	21	12
14	14	18	30	12	29	29	10	30	20
15	15	10	24	14	30	30	7	23	16

Table 3. Marks of control group test

No.	Respondent	Pre-test	Post-test	Difference	No.	Respondent	Pre-test	Post-test	Difference
1	31	11	9	-2	16	46	22	15	-7
2	32	2	9	7	17	47	8	13	5
3	33	10	7	-3	18	48	7	15	8
4	34	10	18	8	19	49	14	11	-3
5	35	17	12	-5	20	50	11	10	-1
6	36	4	9	5	21	51	12	14	2
7	37	11	9	-2	22	52	2	8	6
8	38	6	2	-4	23	53	8	9	1
9	39	5	5	0	24	54	6	5	-1
10	40	8	8	0	25	55	11	18	7
11	41	14	8	-6	26	56	11	12	1
12	42	8	10	2	27	57	8	16	8
13	43	8	8	0	28	58	12	9	-3
14	44	22	15	-7	29	59	7	13	6
15	45	17	18	1	30	60	10	8	-2

Based on the findings, there is a significant difference between pre-test and post-test in the treatment group compared to the control group. In the treatment group, several two-digit values appear in the difference column, along with only one negative integer. Meanwhile, in the control group, there are no two-digit values in the difference column and many of the values are negative integers. Besides that, specific respondents in the treatment group, such as R10, R25, and R29, showed a pre-test and post-test score disparity of 20, while the highest difference among respondents in the control group (R34 and R48) was only 8.

The results indicate that the PBL approach is effective compared to the conventional teaching method. The analysis supports the theory that PBL is a systematic problem-solving skills that enable students to explore themselves and combine knowledge from other sources and fields to find logical solutions that can be used in real-life situations [13]. These results directly address the problem identified earlier as Malaysian students lag in PISA rankings and scientific knowledge. The significant improvement in the treatment group after PBL intervention indicates that traditional methods are less effective at fostering critical thinking and knowledge integration compared to PBL [14]. Thus, the evidence supports that the treatment group exposed to PBL has significant academic achievement improvement compared to the control group, as the treatment group exhibited multiple double-digit scores [15].

### 3.2. Independent t-test

The analysis of the independent t-test for the pre-test is to check the equivalence of both treatment and control groups before PBL intervention. This is to check whether students' previous level of knowledge in science subjects is the same or not between the two groups. As seen in Table 4, the mean of the control group is slightly higher than the treatment group and the standard deviation is about the same. The null hypothesis states that the distribution of pre-test scores between the treatment and control groups is approximately similar.

Based on Table 5, the p-value for the pre-test is 0.325 which is greater than 0.05 ( $>0.05$ ). Thus, the null hypothesis is accepted. The results of the analysis displayed by both groups are insignificant ( $0.325 > 0.05$ ). Hence, the two groups were not significantly different based on their previous knowledge of science subjects.

The treatment and control groups' post-test scores are compared using an independent t-test. This analysis shows which respective groups have higher learning achievement after PBL intervention. Table 6 shows the difference in mean value in the post-test of both treatment and control groups. The finding clearly shows that the mean score of the treatment group is 18.30 (SD=7.498), while the mean score of the control group is 10.07 (SD=4.057).

Table 4. Group statistics pre-test

Activity	Group	N	Mean	Std. Deviation	Std. Error mean
Pre-test score	Treatment	30	9.67	4.634	0.846
	Control	30	10.07	4.891	0.893

Table 5. Independent sample test (pre-test)

Activity	Equality of variances	t-test for equality of means						95% confidence interval of the difference		
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. Error difference	Lower	Upper
Pre-test score	Equal variances assumed	0.080	0.779	-0.325	58	0.746	-0.4	1.230	-2.863	2.062
	Equal variances not assumed			-0.325	57.831	0.746	-0.4	1.230	-2.863	2.062

Table 6. Group statistics post-test

Activity	Group	N	Mean	Std. Deviation	Std. Error mean
Post-test score	Treatment	30	18.30	7.498	1.369
	Control	30	10.07	4.057	0.741

As shown in Table 7, analysis using a t-test presented there was a significant improvement in post-test scores in the treatment group compared to the control group. The p-value is 0.001 which is smaller than 0.05. Thus, the null hypothesis is rejected ( $p=0.001<0.05$ ). Hence, it is proven that students exposed to the PBL method scored better results than students exposed to the conventional teaching method.

The problem-solving questions play a major role in creating a PBL classroom environment. According to Kim [16], PBL questions are open-ended questions with many possible answers that motivate students to participate in the teaching and learning process which is in contrast with traditional classroom which emphasizes answers from textbooks only [17]. Consequently, students are more confident in presenting their answers since there are many possible ways to find solutions based on the given PBL scenario [18]. Unlike traditional classrooms that focus primarily on textbook answers, PBL fosters a dynamic learning experience where students explore diverse solutions to real-world problems [19]. This analysis is supported by students' perceptions about PBL that it increases their self-confidence in learning science. This aligns with the findings of Kardoyo *et al.* [7] which emphasize that the teachers' critical role in proper scaffolding boosts students' critical thinking skills in answering PBL questions. Besides that, the PBL intervention showed a positive impact on student's academic performance because students develop their long-term memory which helps retain facts over a period [20]. This is proven by Ahamad *et al.* [21] in their findings that the in-depth discussion and retention of memory in any subject.

Table 7. Independent sample test (post-test)

Activity	Equality of variances	t-test for equality of means					95% confidence interval of the difference			
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
Post-test score	Equal variances assumed	12.011	0.001	4.840	58	0.0	7.533	1.556	4.418	10.649
	Equal variances not assumed			4.840	44.642	0.0	7.533	1.556	4.418	10.668

### 3.3. Paired t-test for treatment group

This is to prove whether the PBL method is effective on students learning achievement in science subjects. The analysis demonstrated that there is a significant difference between scores. The significant p-value is 0.001 which is smaller than 0.05 ( $p\text{-value}=0.001<0.05$ ). Therefore, the PBL method is effective because it improves the learning achievements of students in science subjects [22]. Table 8 shows the paired t-test results. The data proves students connect previous knowledge with existing knowledge to solve problems given which prevents the rote memorization learning process, additionally enabling them to think critically and analytically [23].

Table 8. Paired t-test for pre-test and post-test for treatment group

Activity	Paired differences							
	Data descriptive			95% confidence interval of the difference		t	df	Sig. (2-tailed)
	Mean	Std Deviation	Std. Error mean	Lower	Upper			
Pair 1 Pre-test score-post-test score	-8.633	6.189	1.130	-10.945	-6.322	-7.640	29	0.0

Ng and Adnan [24] mentioned students prefer to do presentations of group work in front of the class. According to Yuliawati and Wasis [25], teachers were the major reason for the poor STEM education system, however, the integration of PBL in the learning process changed from a teacher-centered to a student-centered classroom and students actively participated in the lessons. Hence, teacher training and professional development in PBL methodologies are crucial to ensure effective implementation [26]. The results were consistent with another research conducted among students from Semarang, Indonesia that real-life problem questions draw students' interest in learning mathematics, and they were able to see the growth of creativity

skills to solve the problems [27]. However, the effectiveness of PBL can be enhanced by the teachers' effort in developing learning modules that make students more active and engaged in the classroom teaching-learning process [7]. This approach has also increased students' motivation and interest in studying science [28], [29].

#### 4. CONCLUSION

In conclusion, this study successfully meets its objectives by demonstrating that PBL is effective in improving students' science achievement, as evidenced by the independent and paired t-test results. Students from the treatment group scored higher in the post-test compared to control group students. Besides that, treatment group students showed drastic improvement in post-test after the exposure to the PBL method. The study found that PBL significantly improved students' science learning achievements. The treatment group PBL outperformed the control group in post-tests. Hence, the PBL method should be implemented in all secondary schools to improve students' science knowledge.

The study recommends that adopting PBL in secondary schools could address prevalent challenges in Malaysian science education, fostering student engagement and deepening their understanding of scientific concepts. Also, the creative and innovative teaching method boosts teachers' self-esteem to conduct science classes. This shift away from traditional teaching methods, which often rely on rote memorization, can foster a deeper understanding of scientific concepts and prepare students for real-world challenges. Further research could explore how PBL impacts other cognitive and social skills, such as collaboration and creativity, or examine its long-term effects on students' academic and career achievements. Additionally, future study should examine the effects of PBL on other cognitive and social skills, such as collaboration and creativity, and explore the long-term impact on students' academic and career paths. Conducting qualitative studies, including student interviews, could provide valuable insights into their experiences with PBL. Finally, incorporating digital tools and technology to enhance the PBL experience may offer additional avenues for student engagement and resource accessibility, further strengthening the approach's effectiveness. Teacher training programs focusing on PBL methodologies are also crucial to support effective classroom implementation and sustainable improvements in science education.

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C : Conceptualization

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## CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest in competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

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