

IMPLEMENTATION OF THE PBL MODEL INTEGRATED WITH STEM-EDP TO IMPROVE NUMERACY LITERACY SKILLS IN HIGH SCHOOL STUDENTS

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Abstract :

The Importance of Numeracy Literacy Skills in High School Students and the Effectiveness of the PBL Model Integrated with STEM-EDP. Numeracy literacy skills in students need to be improved, as these skills are essential in 21st-century education. This study aims to describe the effectiveness of implementing the PBL model integrated with STEM-EDP to enhance high school students' numeracy literacy skills on straight motion. The research was conducted at SMAN 13 Bandar Lampung using a quantitative experimental approach with a nonequivalent pretest-posttest control group design. The instrument used was an essay test. Learning with the PBL-STEM-EDP model has improved students' numeracy literacy skills. This is evident from the average N-gain score in the experimental class, which was 0.79, compared to 0.33 in the control class. These data indicate a significant difference in numeracy literacy skills between the experimental and control classes. This finding is supported by the results of the Independent Sample T-Test, Paired T-Test, and ANCOVA, which yielded a Sig. (2-tailed) value of $0.000 < 0.05$. Thus, it can be concluded that the PBL model integrated with STEM-EDP is effective in improving students' numeracy literacy skills. Additionally, the effect size value of 0.802 indicates that the PBL-STEM-EDP model has a strong influence on enhancing students' numeracy literacy skills. Future researchers should not only observe students' initial and final abilities but also examine the learning process in more detail.

Keywords: EDP, Numeracy Literacy Skills, PBL, STEM

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INTRODUCTION

In the 21st century, the STEM approach in Indonesia has developed rapidly. This is driven by the need to prepare the nation's future generations (Mu'minah, 2021). Along with this, more schools have begun implementing innovative STEM approaches in learning (Abdi et al., 2021; Mardhiyattirrahmah et al., 2020; Sasmita & Hartoyo, 2020). This indicates that more teachers and institutions understand that STEM is highly suitable for supporting 21st-century education (Diana & Turmudi, 2021). 21st-century education focuses on helping the current generation adapt to societal conditions where technology and information systems are highly advanced. To achieve this, students must develop critical thinking, communication, collaboration, and creativity skills (Arsanti et al., 2021).

Additionally, 21st-century learners are required to be proficient in multi-dimensional literacy. Multi-dimensional literacy consists of reading and writing literacy, numeracy skills, digital literacy, information skills, cultural awareness, and emotional and social intelligence (Faridah et al., 2022). One of the multi-dimensional skills that remains low in Indonesia is numeracy literacy (Danuri et al., 2023; Syamsyiah & Handayani, 2023). This is supported by data from PISA 2022, which indicates that Indonesia's numeracy literacy skills are still relatively low (OECD, 2023). In reality, numeracy literacy is crucial for interpreting results, making predictions, and making decisions in everyday problem-solving (Wati & Syafitri, 2022). In physics education, numeracy literacy is particularly important for students to solve problems related to physics concepts in real life (Aldina & Rusilowati, 2024; Sartianis et al., 2022).

Physics learning is always related to numeracy literacy, one example being linear motion. This is because, in this topic, students must use formulas, apply equations, interpret graphs and tables, and understand physical phenomena (Palit et al., 2022). The numeracy literacy skills required for linear motion can be enhanced through specific learning models. Learning models that can improve numeracy literacy skills include problem-based learning, inquiry-based learning, project-based learning, question-based learning, integrated learning, realistic mathematics education, blended learning, and observational learning. Each of these approaches has a unique focus and method for developing students' understanding and skills (Nurcahyono et al., 2023).

Several previous studies have shown that problem-oriented learning models, such as Problem-Based Learning (PBL), can enhance students' numeracy literacy skills (Ambarwati & Kurniasih, 2021; Anugrah & Sarnawiah, 2023; Nisa, 2023). However, PBL has limitations, particularly for students with low engagement and motivation, as they struggle with problem-solving (Hermansyah, 2020). Therefore, the PBL model must be combined with an appropriate approach to maximize numeracy literacy skills, such as STEM (Science, Technology, Engineering, and Mathematics) and the Engineering Design Process (EDP) strategy (Arnida & Wibowo, 2022; Kurniati et al., 2021; Parno et al., 2020; Sulaiman et al., 2023).

STEM-EDP is a suitable approach to integrate with the PBL model in physics learning. EDP is a strategy used in STEM education that teaches students how to design and develop prototypes to solve problems (Abdurrahman et al., 2023). In STEM education, the Engineering Design Process (EDP) strategy can be utilized to address problems through cognitive, motor, and social aspects (Aini et al., 2024).

However, field observations at a senior high school in Bandar Lampung indicate that numeracy literacy levels remain low. This is supported by an interview with a teacher at SMAN 13 Bandar Lampung on August 12, 2024. It was revealed that the learning process at the school primarily employs the direct instruction model. According to the teacher, students' performance in physics is still lacking, particularly in topics requiring numeracy literacy skills, such as linear motion. Only about 30% of students can use numerical and mathematical symbols correctly. Around 50% can understand and analyze data in the form of graphs, charts, and diagrams. However, only about 10% can interpret analysis results and draw conclusions.

Based on the background presented, it is evident that 21st-century STEM approaches are important and are experiencing rapid growth. However, field findings indicate that certain 21st-century competencies, particularly numeracy literacy skills, remain low. This is further supported by interview data. Therefore, the proposed solution is to implement a Problem-Based Learning (PBL) model integrated with the STEM approach and the EDP strategy in the classroom. This study is titled:

"Implementation of the STEM-EDP Integrated PBL Model to Improve Senior High School Students' Numeracy Literacy Skills."

RESEARCH METHOD

Research Design

The design of this study is quantitative experimental research, which tests hypotheses by observing the effects of specific treatments on variables related to the research outcomes. The research method used is a quasi-experiment with a nonequivalent pretest-posttest control group design. This design involves two classes: the experimental class, which receives the treatment, and the control class, which does not receive the treatment. Both classes undergo pretests and posttests to measure changes in numeracy literacy skills. This design was chosen because the study aims to examine the effect of the PBL-STEM-EDP model on improving students' numeracy literacy skills (Creswell & Creswell, 2022)

Population and Research Sample

This research was conducted at SMAN 13 Bandar Lampung, located at Jl. Padat Karya Sinar Harapan, Rajabasa Jaya, Rajabasa District, Bandar Lampung City, Lampung. The population in this study consisted of all 11th-grade students in the first semester of the 2024/2025 academic year at SMAN 13 Bandar Lampung. The sampling technique used was purposive sampling. The sample consisted of class XI F 3 and XI F 4. Class XI F 4 served as the experimental class, implementing the PBL-STEM-EDP model, while class XI F 3 acted as the control class, using the Direct Instruction model.

Data Collection Techniques

The data collected in this study consists of student learning outcomes, obtained through a test technique. The tests administered were essay-based questions, including both a pretest and a posttest, which were given to all students in both the experimental and control classes. The pretest was conducted before the learning process began. The posttest was conducted after the learning process was completed. The average N-gain **score** was calculated from the pretest and posttest results. The purpose of these tests was to measure the improvement in students' numeracy literacy skills in the experimental class, which implemented the PBL-STEM-EDP model, compared to the control class, which used the Direct Instruction model.

Research Instrument

The instrument used in this study consists of 10 essay questions. This test is designed to assess students' numeracy literacy skills. The instrument is applied in two stages: a pretest and a posttest. Thus, it serves to measure the improvement in students' numeracy literacy skills throughout the research period.

Data analysis technique

The data analysis technique used in this study is inferential quantitative analysis. The collected data was analyzed using IBM SPSS Statistics 26.0 software. The tests conducted included the N-gain test, normality test, and homogeneity test. Furthermore, hypothesis testing was performed using the independent sample t-test, paired sample t-test, and effect size analysis in ANCOVA.

Research Procedure

The research process was divided into three stages, as follows:

1. Research Preparation Stage

The activities conducted in this stage included:

- a. Requesting permission from the school to conduct research at SMAN 13 Bandar Lampung.
- b. Conducting interviews with physics teachers at SMAN 13 Bandar Lampung to identify students' learning difficulties in physics.

- c. Determining the research sample.
- d. Reviewing relevant theories related to the research topic
- e. Developing teaching modules and designing research instruments for data collection.
2. Research Implementation Stage
The activities conducted in this stage are summarized in Table 1.

Table 1. Implementation Stage

Experimental Class	Control Class
The researcher administered a pretest to measure students' initial numeracy literacy skills.	The researcher administered a pretest to measure students' initial numeracy literacy skills.
The researcher conducted the learning process on the straight motion topic using the PBL-STEM-EDP model.	The researcher conducted the learning process on the straight motion topic using the Direct Instruction model.
The researcher administered a post-test to students.	The researcher administered a post-test to students.

3. Final Research Stage
The activities conducted in this stage included:
 - a. Processing pretest and posttest data, along with supporting instruments.
 - b. Comparing the results of test instrument analysis before and after treatment to determine whether there is a difference in numeracy literacy skills between the experimental and control classes.
 - c. Drawing conclusions based on data analysis results and compiling the research report.

RESULTS AND DISCUSSION

This study was conducted to determine the effect of the PBL STEM-EDP model on the topic of linear motion in improving students' numeracy literacy skills. In the experimental class, the researcher implemented the PBL STEM-EDP model, while in the control class, the direct instruction model was used. The learning activities were conducted directly by the researcher. To assess students' numeracy literacy skills, pretests and posttests were administered in both classes.

The average posttest score in the experimental class, which applied the PBL STEM-EDP model, was higher at 86.71 compared to the control class, which used the direct instruction model, with an average score of 55.85. This finding aligns with previous research stating that the average posttest score in the experimental class, which received treatment, was higher than in the control class, which did not receive treatment (Ambarwati & Kurniasih, 2021). The results of the N-Gain test in both classes after the treatment can be seen in Figure 1.

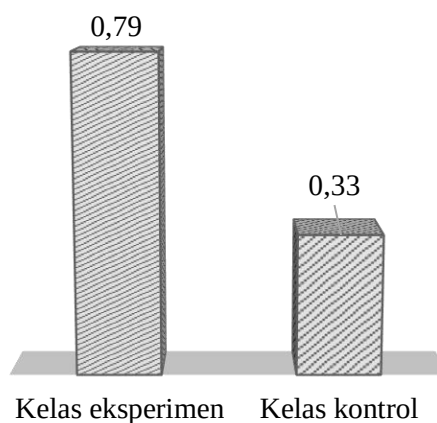


Figure 1. Graph og N-Gain

Figure 1 shows that the learning process in the experimental class using the PBL STEM-EDP model was more effective compared to the control class, which used the direct instruction model. After the treatment, the experimental class achieved an average N-Gain of 0.79, categorized as high, while the control class obtained an average N-Gain of 0.33, categorized as moderate. This finding is consistent with previous research stating that the experimental class achieved a higher average N-Gain than the control class (Masliah et al., 2023). Therefore, it can be concluded that the experimental class using the PBL STEM-EDP model experienced a greater improvement compared to the control class using the direct instruction model.

Based on the normality test results, the Sig. Value in both the experimental and control classes was greater than 0.05, indicating that the data were normally distributed. The homogeneity test results showed a Sig. Value of $0.078 > 0.05$, meaning the data were homogeneous. The results of the normality and homogeneity tests can be seen in Tables 2 and 3.

Table 2. Normality Results

Test Type_Class	Kolmogorov Smirnov			Interpretasi
	Statistic	N	Sig.	
Pretest_Experiment	0,129	32	0,190	Normal
Posttest_Experiment	0,143	32	0,093	Normal
Pretest_Control	0,133	32	0,157	Normal
Posttest_Control	0,150	32	0,065	Normal

Table 3 Homogeneity Results

	Lavene Statistic	df 1	df 2	Sig.	Interpretation
Based on Mean	2,327	3	123	0,078	Homogen
Based on Median	2,042	3	123	0,112	Homogen
Based on Median and with adjusted of	2,042	3	105,501	0,112	Homogen
Based on trimmed mean	2,296	3	123	0,081	Homogen

The results of the independent sample T-test showed a Sig. (2-tailed) value of $0.000 < 0.05$, meaning that H_0 was rejected and H_1 was accepted. This indicates a significant difference in the average scores between the experimental class, which received treatment using the PBL STEM-EDP model, and the control class, which was taught using the direct instruction model. The results of the independent sample T-test can be seen in Table 4.

Table 4. Results of the Independent Sample T-test

Class	N	Mean	Std. Dev	T	Sig. (2-tailed)
Eksperiment	32	86,7188	6,26812	15,792	0,000
Control	32	55,8594	9,10533	15,792	0,000

The results of the paired T-test showed a Sig. (2-tailed) value of $0.000 < 0.05$ in the experimental class. This means that H_0 was rejected and H_1 was accepted, indicating a significant improvement in students' numeracy literacy skills before and after being taught with the PBL STEM-EDP model. Similarly, in the control class, the Sig. (2-tailed) value was $0.000 < 0.05$, leading to the rejection of H_0 and the acceptance of H_1 . This suggests that there was also an improvement in numeracy literacy skills before and after the direct instruction model was implemented. The results of the paired T-test can be seen in Table 5.

Table 5. Results of paired T-test

Class	N	Mean	Std. Dev	T	Sig. (2-tailed)
Pretest_Experiment	32	-51,093	8,91	-32,434	0,000

Posttest_Experiment	32	-22,578	11,33	-11,271	0,000
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The ANCOVA test results showed a Sig. value of $0.000 < 0.05$, meaning that H_0 was rejected and H_1 was accepted. This confirms that the PBL STEM-EDP learning model was effective in improving students' numeracy literacy skills. The effect size value, as indicated by the partial eta square, was 0.802, which falls into the high category. This means that the PBL STEM-EDP model had a strong impact on enhancing students' numeracy literacy skills, contributing to 80.2% of the observed improvement. This finding aligns with previous research stating that the Problem-Based Learning model significantly influences numeracy literacy skills, as indicated by a substantial effect size value (Ambarwati & Kurniasih, 2021). The ANCOVA test results can be seen in Table 6.

Table 6. ANOVA test results

Source	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2	7624,723	123,193	0,000	0,802
Intercept	1	8315,950	134,361	0,000	0,688

Numeracy literacy skills were measured using a test instrument, which included 10 essay questions developed according to PISA's numeracy literacy indicators. These questions were administered before the learning process (pretest) and after it (posttest). Based on the pretest and posttest results, it can be concluded that the PBL STEM-EDP model is effective in improving numeracy literacy skills. The learning process in the experimental class used the Problem-Based Learning model (Arends, 2012), combined with the STEM approach (Kelley & Knowles, 2016), and integrated with the EDP strategy (Long et al., 2020). This model was used to enhance students' numeracy literacy skills according to PISA (OECD, 2023). This is because students' numeracy literacy skills are still relatively low and need improvement (Nasoha et al., 2022; Wati & Syafitri, 2022).

The PBL STEM-EDP model consists of several stages. The first stage is the problem orientation, which covers the science and technology aspects of the STEM approach and includes the "ask" phase in the EDP strategy. At this stage, students are shown a video related to a phenomenon in daily life and then asked to formulate problems based on the phenomenon in the video. This aligns with the constructivist theory, which states that students should be active in building their knowledge. The teacher acts as a facilitator, and students need to actively ask questions and seek information to gain cognitive understanding (Masgumelar & Mustafa, 2021; Sugrah, 2020).

The second stage involves organizing students, which covers science, technology, and engineering aspects in STEM and includes the "research" and "imagine" phases in the EDP strategy. At this stage, students are divided into small groups and discuss plans to create a prototype. The group work process enhances students' understanding. This is in line with the Zone of Proximal Development (ZPD) framework, which suggests that social interaction support can help students achieve a higher level of understanding. Within the group, students can discuss and exchange ideas, thereby improving their cognitive abilities (Vygotsky, 2012).

The third stage focuses on assisting with individual and group investigations, which includes the "plan" and "create" phases in the EDP strategy. At this stage, students design and prepare materials and tools to create a prototype for solving the problem (Suhartono et al., 2023). According to previous research, Problem-Based Learning is a teaching model designed to help students solve real-life problems, improve teamwork, and critical thinking in students (Affandy et al., 2024; Anggraeni et al., 2023; Ardianti et al., 2021; Marcinauskas et al., 2024). Students then proceed to create prototypes based on their designs. This is consistent with previous studies, which indicate that the EDP strategy teaches students how to design prototypes to solve problems (Abdurrahman et al., 2023).

The fourth stage involves developing and presenting the results, which includes science, technology, engineering, and mathematics aspects in the STEM approach and the "test" and "evaluate" phases in the EDP strategy. At this stage, students test the prototypes they have created, record the data obtained, and analyze it using the equations for straight-line motion. They then present their findings to the class. This Problem-Based Learning process enhances students' numeracy literacy, especially when analyzing the data obtained during the prototype testing. Previous research has shown that numeracy

literacy improves when students are involved in Problem-Based Learning stages (Anugrah & Sarnawiah, 2023).

The final stage involves analyzing and evaluating the problem, which includes the science, technology, engineering, and mathematics aspects of the STEM approach and the "improve" phase in the EDP strategy. At this stage, students reflect on the learning process. They realize that physics knowledge can be integrated with other subjects and applied through the STEM approach. This helps increase students' interest in learning physics and trains them to think critically, preparing them for the workforce, and have high order thinking skills (Foundation, 2020; Kanza et al., 2020; Pane et al., 2021; Septiani et al., 2020). Students then refine their prototypes if necessary and conclude the learning process. This aligns with Simon (2019), who stated that feedback and evaluation are important in the design process.

Based on the discussion above, it can be seen that the PBL STEM-EDP model improves students' numeracy literacy in straight-line motion. This is consistent with research by (Suharyani et al., 2023) which states that students' numeracy literacy improves when specific treatments are applied during the learning process. One of the learning models that can be applied is PBL, which has been shown to improve students' numeracy literacy (Anugrah & Sarnawiah, 2023).

To improve students' skills in the 21st century, especially their numeracy literacy, the PBL model needs to be integrated with an appropriate approach, namely the STEM approach (Muttaqiin, 2023). This is supported by the posttest results, where the average score in the experimental class using the PBL STEM-EDP model was higher than in the control class using direct instruction. Additionally, the improvement in numeracy literacy was also evident from the SPSS test results. Thus, it can be concluded that the PBL STEM-EDP model is effective in improving students' numeracy literacy skills.

CONCLUSION

Based on the research findings, it can be concluded that the PBL STEM-EDP learning model is effective in improving students' numeracy literacy skills. This is demonstrated by the average N-Gain score in the experimental class, which was 0.79, higher than the control class with an average N-Gain score of 0.33. Additionally, hypothesis testing using the Independent Sample T-Test resulted in a Sig. (2-tailed) value of $0.000 < 0.05$, indicating a significant difference in numeracy literacy skills between the experimental and control classes. This is further supported by the results of the paired sample T-test, which showed a Sig. (2-tailed) value of $0.000 < 0.05$, proving that there was an improvement in students' numeracy literacy skills after being taught using the PBL STEM-EDP model. Moreover, the ANCOVA test results also showed a Sig. (2-tailed) value of $0.000 < 0.05$, confirming that the PBL STEM-EDP learning model is effective in enhancing students' numeracy literacy skills. The level of effectiveness or the impact of this learning model can be seen from the effect size value of 0.802, which falls into the high category. Future research should focus on a more detailed analysis of each numeracy literacy indicator to optimize students' numeracy skill development. This approach allows for a deeper understanding of which aspects improve the most and which still require further enhancement during the learning process. Additionally, observations should not only focus on initial and final learning outcomes (assessment of learning) but also include the learning process (assessment for learning). This will provide deeper insights into how students develop their numeracy literacy throughout the learning experience, rather than just evaluating the final results.

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