



STEM-Based PBL Model Influences Students' Numeration and Critical Thinking Ability in the Arithmetic Sequence Unit

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Article Info	Abstract
<p>Keywords: <i>arithmetic sequences; critical thinking; numeracy skills; PBL; Tapak STEM-based Project-Based Learning;</i></p> <hr/> <p>Received: 10/05/2026 Revised: 19/05/2026 Accepted: 04/06/2026</p>	<p>Background: Students' numeracy and critical thinking skills in learning arithmetic sequences are still relatively low because classroom instruction tends to be teacher-centered and provides limited opportunities for students to engage in problem-solving activities. Therefore, an innovative learning model is needed to improve these abilities. This study aims to examine the effect of the STEM-based Problem-Based Learning (PBL) model on students' numeracy and critical thinking skills and to compare its effectiveness with the conventional Problem-Based Learning (PBL) model.</p> <p>Methods: This study uses a quantitative approach with a quasi-experimental design to analyze the effect of the STEM-based Problem Based Learning (PBL) model on students' numeracy and critical thinking skills in arithmetic sequences. The research subjects consisted of 56 grade XI students divided into an experimental class and a control class, each consisting of 28 students. The experimental class implemented the STEM-based PBL model, while the control class used teacher-centered learning according to the National Curriculum. Data were obtained through pre-tests and post-tests using validated test instruments. Data analysis was carried out using normality, homogeneity, N-Gain, and independent sample t-tests.</p> <p>Results: The findings revealed that the mean score of students' numeracy skills in the control class was 7.7188, while the experimental class achieved 10.7500, with a significance value of $0.000 < 0.05$. In addition, the average critical thinking score in the control class was 24.8750, whereas the experimental class reached 35.0313, with a significance value of $0.000 < 0.05$. These findings indicate that the STEM-based PBL model significantly improved students' numeracy and critical thinking skills.</p> <p>Conclusion: The STEM-based PBL model was more effective than the conventional PBL model in improving students' numeracy and critical thinking skills in the arithmetic sequence unit.</p>

INTRODUCTION

The aspect of education is an important indicator in improving the competitiveness of human resources in global era. Hence, every level of education needs to be optimally organised as an experience to learn i.e., for example at the elementary stage. Mathematics education is an integral part of this as it helps drive logical, systematic, and critical thought in the context. Mathematics education is an essential part of the curriculum in schools, as it can develop students' mathematical attention dealing with logical and realize analytic thinking also problem-solving skills on daily basis (Hadi et al., 2025). Mathematics education at the elementary level is essential to supporting students' logical thinking, which can be accomplished by performing mathematic activities that encourage students to analyze mathematical situations, generalize solutions, apply reasoning to concepts and terms when understanding mathematics (Mingjing & Yidi, 2022). Elementary mathematics teaching itself is oriented to prepare students with all kinds of thinking skills e.g. logical, analytical, systematic, critical and creative thinking are required to understand any concept and solve various problems (Muhammad Fathoni & Haryani, 2018).

Scientific and technological advancements require students to develop skills in numeracy. Yet Indonesian students still recorded a measly numeracy score of 366 in the Program for International Student Assessment (PISA) test 2022, well below the OECD average of 472. This data shows that Indonesian students indeed still have low numeracy skills which require us to innovate in mathematics instruction so that we can improve the understanding and thinking skills of students more effectively. Arithmetic sequences is where numeracy and critical thinking are intertwined with the messiness of raw disputes. This not only necessitates recognition of number patterns but also involves relational understanding, generalization and solving contextual problems.

Making sense of math concepts closely relates to students gaining the ability to think abstractly. Students are it can explain their understanding this much influenced the extent to which students are able to think critically, and able to establish a relationship between concepts, so that both critical thinking skills as well as solving mathematical problems (Oktaviani et al., 2023). In addition, mathematical conceptual understanding includes to not only perform the number calculation procedures; it also requires for students to understand reasoning and strategic approaches in solving mathematical problems (Balt et al. Cognitive development is a mental process that deals with the way in which individuals are able to understand, process and utilize information with their thinking (Balt et al., 2020). Specifically, when it comes to learning mathematics, the students not only need to memorize formulas but also understand thoroughly concepts and their use.

Numeracy is applying mathematics to make sense of the world, developing ability for students to be quantitative information analyzers and systematic decision makers for problem-solving (Rediani, 2024). For this reason, mathematics instruction needs to be backed by an approach that can best prepare students with numeracy and critical thinking skills. But the empirical evidence suggests that mathematics instruction continues to be remorselessly traditionalist and teacher-centred. Teacher-centered learning leads students to be passive, merely memorizing the procedures for solving problems as opposed to understanding concepts in mathematics (Balt et al., 2020). The outcome is students not developing adequate numeracy or very little being done to develop their critical thinking when in arithmetic sequences, a topic that requires mathematical reasoning.

In addition, the novelty of learning models has not been implemented well, it becomes an obstacle for students to relate mathematical concepts with real life situations. The wide range of learning exactly helps students to understand abstract concepts, but not if since the teacher has

only limited kind of this learning model (Edu et al., 2021). STEM-based Problem-Based Learning (PBL) is one of the methods that are thought to be able to resolve these problems. STEM based learning is problem based in balancing the disciplines of Science, Technology, Engineering and Mathematics when discovering solutions to contextual problems through critical, creative and collaborative thinking. Problem-based learning improves student motivation as students are engaged in research, analysis, and solution-designing processes relevant to a particular problem that needs solving.

Research show the STEM-based learning type might enhance students' capabilities such as problem solving, critical thinking and comprehension of basic mathematical ideas because learning occurs through exploration and application of a concept (Chi et al., 2018). Nonetheless, there is relatively little research focusing on the effects of the STEM-Based PBL model on numeracy and critical thinking, especially when looking into content in arithmetic sequences (Fitriani et al., 2024). Based on this, the objective of this study is to prove the influence of STEM-Based PBL model on students' numeracy and critical thinking in an arithmetic sequence. This research is anticipated to support the development of more lively, contextual, and significant mathematics learning innovations and can be a reference for teachers in conducting STEM-based learning patterns to improve the quality of mathematics education in schools.

METHODS

This study uses a quantitative approach with an experimental research design because the data that has been collected is quantitative, which will be analyzed in statistical techniques (Sugiyono, 2015). The quantitative approach was selected because it involves systematic steps allowing a structured investigation for the researcher. This research is designed as a quasi-experimental, aimed to test the effect of implementing STEM-Based Problem Based Learning (PBL) model on students Numeracy and Critical Thinking skills on arithmetic sequence, both in the experimental class and the control class (Shidqi et al., 2025). The subjects of this research were 56 eighth grade students of a junior high school, the experimental class was Class XI-A (28 students) and control class was XI-B (28 Students). Saturation sampling was used, where the whole population is also the research sample. The experimental group received learning treatment using empowered STEM-based PBL model. Meanwhile, the control group received learning using the learning model recommended in the National Curriculum, with a more teacher-centered approach.

Research data was collected using pre and post-test methods. Before conducting the intervention, both of these groups were administered a pre-test that explored students' initial numeracy and critical thinking skills related to arithmetic sequences; following the intervention, they had to answer a post-test designed to assess increments in students' performance. The research instrument was developed through a study of theories related to the research variables, namely numeracy and critical thinking skills. Numeracy skills indicators include the ability to use mathematical symbols and operations, interpret data in various forms of representation such as tables, graphs, and diagrams, and apply mathematical concepts to solve contextual problems (Winata et al., 2021). Indicators of critical thinking skills include the ability to analyze information, evaluate opinions or arguments, draw logical conclusions, and provide rational reasoning in problem-solving. Based on these indicators, the test instrument was designed to align with the research objectives and needs (Rendi Rendi et al., 2024). The instrument includes both open-ended and multiple-choice questions with a 1–5 rating scale. Prior to use, the instruments were tested by media and language experts means of SPSS software; items with a coefficient of ≥ 0.632 were considered valid and reliable while values lower than this criterion did not meet requirements

(Sugiyono, 2015). The instrument was administered two students at a time during class and the test scores were retrieved as the analyzing data for the study.

Quantitative analysis of pre-test and post- test results were conducted to answer the research questions. The initial stage of the analysis began with the implementation of prerequisite tests, including normality and homogeneity tests (Wayan, 2016). Based on the test results, the data were declared normally distributed and had homogeneous variance, as the significance value obtained was ≥ 0.05 . The analysis then continued using the N-Gain test to measure the level of improvement in student abilities in the experimental and control classes. This study goal to find out how the implementation of STEM-Based PBL model has a significant effect on students mathematics thinking in arithmetic sequences. Thus, the research results are expected to be empirical evidence of the effectiveness of STEM-Based PBL model on mathematics learning.

RESULT AND DISCUSSION

Mathematics is a subject one studied from elementary school to the end of high school. To study Mathematics in high school, students need to be numerate enough so that the abstract concepts they encounter become transferrable skills for a life beyond school. Traditional mathematics teaching models tend to centre their activities around the teacher, allowing for a more dominant role for the teacher. Teachers need a teaching model capable of developing students' numeracy skills. One teaching model relevant to the development of students' numeracy skills is the STEM PBL model. To demonstrate the impact of the STEM-PBL model on students' numeracy skills, the researcher collected data on numeracy skills from the control group and the experimental group. The data was then analyzed using an independent samples t-test. The following is a description of the results of the independent samples t-test analysis of the numeracy ability data for the control and experimental groups:

Table 1. Group Statistics (Numeracy Skills)

Learning Models		N	Mean	Std. Deviation	Std. Error Mean
Numeracy Skills	Conventional Model	32	7.7188	1.14256	32
	Stem Project-Based Learning Model	32	10.7500	1.16398	32

Table 2. Independent Samples Test (Numeracy Skills)

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Numeracy Skills	Equal variances assumed	62	.000	-3.03125
	Equal variances not assumed	61.979	.000	-3.03125

Based on the results of the independent samples t-test analysis of the numeracy ability data for the control and experimental groups above, a significance score (two-tailed) of 0.000 was obtained, which is less than 0.05. Thus, the researcher concludes that the STEM-PBL Model has an effect on the numeracy abilities of 10th-grade students at SMAS Puteri Attanwir Sampang regarding arithmetic sequences. Studying mathematics in high school requires adequate critical thinking skills so that students can more easily understand the mathematical concepts being taught and apply them in daily life. Mathematics instruction using conventional learning models centers activities on the teacher, making the teacher more dominant. A learning model that can develop critical thinking in students is needed for teachers. One model of learning that has a direct impact on the development of student critical thinking skills is the STEM PBL model. To show that the STEM PBL model has an effect on students' critical thinking skills, researchers collected data

on critical thinking skills from control and experimental groups. The independent samples t-test was then used to analyse this data. Independent samples t-test analysis of the critical thinking skill data for control and experimental group is showned as follow:

Table 3. Group Statistics (Critical Thinking)

	Learning Models	N	Mean	Std. Deviation	Std. Error Mean
Critical Thinking	Conventional Model	32	24.8750	3.89168	.68796
	Stem Project-Based Learning Model	32	35.0313	3.93073	.69486

Table 4. Independent Samples Test (Critical Thinking)

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Critical Thinking	Equal variances assumed	.000	-10.15625	.97781
	Equal variances not assumed	.000	-10.15625	.97781

The data analysis of critical thinking ability in classes using the STEM-PBL models as per stages above resulted in significance scores (two-tailed) based on independent samples t-test of 0.000 (< 0.05). Based on the research results, it can be concluded that there is a difference in the effect of STEM PBL model against students' critical thinking skills about IOS in class X at.

This research shows that the implementation of STEM-based Problem-Based Learning model contributes to students' numeracy and critical thinking skills in arithmetic sequences. Statistical test results indicate a p-value of less than 0.05, thus proving validity for the research hypothesis. Statistically, the mean post-test of experimental class was larger compared to control class. These findings suggest that the STEM-based PBL model is more effective in improving students' understanding of mathematical concepts than conventional learning (Sudarsono et al., 2026). The positive impact of STEM-based learning on students' capabilities has been demonstrated, since the process directly integrates problem-solving, investigative activities and application of mathematical concepts in real-life situations, thus allowing students better to comprehend how concepts are interrelated (Sari et al., 2026). These findings align with previous studies that suggest that STEM-based learning can improve students' critical thinking skills, problem-solving skills, and mathematics learning outcomes (Dewi et al., 2023). This approach provides students with the opportunity to actively engage in investigative, collaborative, and problem-solving activities related to real-world situations, thereby enhancing the learning process. Furthermore, integrating PBL with the STEM approach encourages students to think logically, systematically, and creatively in solving mathematical problems (Rahmi & Rini, 2025). Therefore, the findings of this study further demonstrate that the implementation of the STEM-based PBL model is an effective learning strategy for enhancing students' cognitive abilities, particularly in mathematics.

Due to the reality that students are trained to apply symbols, mathematical operations and data analysis in order to address contextual problems in connection with real-life roles, even mathematics taught through STEM-based PBL has also been established to improve the numeracy skills of students. Problem based learning helps students bridge the gap from abstract mathematical ideas to real world problem solving, setting a context for learning (Alfita et al., 2025). This is in line with the perspective that learning that combines multiple representations of concepts can improve student understanding of material (Setiawati et al., 2024). Moreover, since active learning approaches involve discussion, exploration and problem-solving activities among the students which lead to a better well-rounded learning experience, it can enhance cognitive outcomes for students (Manulang et al., 2024).

The key findings of this study are consistent with the principles of constructivist learning, such as that students create knowledge through experiences. STEM-based learning empowers students to process information through the analysis, exploration and inquiry methods of their activities, maximising their development of critical thinking skills (Azizah & Angelina, 2025). Learning to read in different forms of information representation allows students to develop a deeper conceptual understanding, as learners can connect their new knowledge with their previous experience (Çeken & Taşkın, 2022). Similarly, other research has also suggested that interactive learning in mathematics can support students' conceptual understanding due to the application of visualization and problem-solving activities help the learners understand an abstract concept more easily with concrete classroom environments (Etyarisky & Marsigit, 2022). Therefore, STEM-based PBL assists students not only in understanding problem-solving processes but also improving their grasp of mathematical concepts related to arithmetic sequences.

In addition to improving students' critical thinking skills, student engagement and attention in the learning process also have a positive effect. The PBL model based on STEM is more engaging and student-centred than lecture-based methods (Yuniar & Hadi, 2023). By having group discussions, problem-solving activities, and project presentations; students are actively engaged in the learning process. Interactive learning can add value to student engagement, because the process of learning becomes more fun and challenging, so they encourage students to be more engaged in other activities (Bawamenewi et al., 2024). These findings show that affective aspects of learning such as interest and motivation to learn are also associated with improvements in students' numeracy and critical thinking skills.

This research results also confirmed previous research that the innovative STEM-based learning model use can improve students' cognitive competence and critical thinking skills. Using STEM-based learning with students has a large effect on student engagement, thus improving their understanding of the material, and problem-solving ability in Mathematics (Norfadila et al., 2024). Nonetheless, this research makes a unique addition in that it focuses on the specific influence highly developmentally effective STEM-based PBL model has on students' numeracy and critical thinking skills with respect to arithmetic sequences at the second high school level. Therefore, this study makes a more focused empirical contribution in the scope of mathematics education research on content perceived by students as difficult.

Theoretical and practical implications of this study. In theory, the findings strengthen existing research about the efficacy of a STEM-based PBL model to support problem-solving in mathematics and higher order thinking. This can be done by means of encouraging teachers to play an active role in the implementation of more innovative learning models based on students becoming active participants (active learning), including one designed with a concept of STEM-based PBL model as another alternative learning strategy with the expectation that this innovative learning strategy can ultimately improve the quality improvement process and student learning outcomes. Educational institutions should also support the use of technology and STEM-based approaches in learning by providing supporting facilities, such as a laboratory that can be fully utilized as well as teachers trained in the area that allows maximum implementation of an optimal role (Dore et al., 2020). The expectation is that, with supportive teachers, innovative curricula and policy reform, mathematical learning may be transformative for school-age children in the areas of numeracy and critical thinking thought.

CONCLUSION

Based on the results and discussion of the study, it can be concluded that the implementation of the STEM-based Problem-Based Learning (PBL) model significantly influenced students' numeracy and critical thinking skills in learning arithmetic sequences among tenth-grade students. Students who participated in learning activities through the STEM-based PBL approach

demonstrated better achievement compared to those who learned through the conventional PBL model. The integration of STEM elements within problem-based learning activities enabled students to understand mathematical concepts more comprehensively, apply problem-solving strategies effectively, and develop critical thinking abilities through contextual and collaborative learning experiences. In addition, the findings indicate that the STEM-based PBL model created a more active and student-centered learning environment, encouraging learners to engage in analysis, exploration, and discussion during the instructional process. The implications of this study suggest that the STEM-based PBL model can be utilized as an alternative instructional approach to improve students' higher-order thinking skills and numeracy competence in mathematics learning. Therefore, mathematics teachers are encouraged to apply STEM-oriented learning strategies more intensively in classroom instruction, while educational institutions should support the implementation of innovative learning models by providing adequate facilities and professional development programs for teachers. Future studies are recommended to involve wider research subjects and different mathematical materials in order to obtain more comprehensive findings regarding the effectiveness of STEM-based learning approaches.

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