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IMPROVING NUMERACY LITERACY WITH PROBLEM-BASED LEARNING INTEGRATED IN AUGMENTED REALITY MEDIA

Hafizha Arwa Dewanti[1*], Wardhani Utami Dewi[2]

[1.2] Universitas Muhammadiyah Metro, Lampung
** Corresponding author. Street Ki Hajar Dewantara, No.116, Iringmulyo, East Metro, Metro City, Lampung*

E-mail: Hafizharwa1211@gmail.com [1*]
wardhaniutamidewi@ummetro.ac.id [2]

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ABSTRACT
The numeracy literacy ability of students in Indonesia is still relatively low, which is reflected in the results of PISA and the Minimum Competency Assessment (AKM) which show that many students are able to solve procedural problems, but have difficulties when facing contextual problems that require data interpretation and mathematical reasoning. This study aims to analyze the improvement of students' numeracy literacy skills through the application of the Problem Based Learning (PBL) model integrated in Augmented Reality (AR) media. The study used a quantitative approach with a one-group pretest–posttest design. The subjects of the study were 29 students of grade VIII Ar-Rasyid SMP Muhammadiyah Ahmad Dahlan Metro who were selected using purposive sampling technique. Data were collected through a numeracy literacy test in the form of essay questions given before and after treatment, then analyzed using the Shapiro–Wilk normality test and the Wilcoxon test with the help of SPSS. The results showed that there was a significant improvement in students' numeracy literacy skills, which was shown by an increase in the average score from 18.52 in the pretest to 68.72 in the posttest and the significance value of the Wilcoxon test of 0.000 (<0.05). It can be concluded that PBL learning that is integrated in AR media is effective in improving students' numeracy literacy skills. The implications of this study show that the integration of problem-based learning approaches with AR technology can be an innovative strategy in mathematics learning to support the strengthening of students' numeracy literacy.
Keywords: augmented reality; numeracy literacy; problem based learning

ABSTRAK
Kemampuan literasi numerasi siswa di Indonesia masih tergolong rendah, yang tercermin dari hasil PISA dan Asesmen Kompetensi Minimum (AKM) yang menunjukkan bahwa banyak siswa mampu menyelesaikan soal prosedural, tetapi mengalami kesulitan ketika menghadapi masalah kontekstual yang memerlukan interpretasi data dan penalaran matematis. Penelitian ini bertujuan untuk menganalisis peningkatan kemampuan literasi numerasi siswa melalui penerapan model Problem Based Learning *(PBL) yang terintegrasi dalam media* Augmented Reality *(AR). Penelitian menggunakan pendekatan kuantitatif dengan desain one-group pretest–posttest. Subjek penelitian adalah 29 siswa kelas VIII Ar-Rasyid SMP Muhammadiyah Ahmad Dahlan Metro yang dipilih menggunakan teknik purposive sampling. Data dikumpulkan melalui tes literasi numerasi berbentuk soal esai yang diberikan sebelum dan sesudah perlakuan, kemudian dianalisis menggunakan uji normalitas Shapiro–Wilk dan uji Wilcoxon dengan bantuan SPSS. Hasil penelitian menunjukkan bahwa terjadi peningkatan yang signifikan pada kemampuan literasi numerasi siswa, yang ditunjukkan oleh peningkatan skor rata-rata dari 18,52 pada pretest menjadi 68,72 pada posttest serta nilai signifikansi uji Wilcoxon sebesar 0,000 (<0,05). Dengan demikian, dapat disimpulkan bahwa pembelajaran PBL yang terintegrasi dalam media AR efektif dalam meningkatkan kemampuan literasi numerasi siswa. Implikasi penelitian ini menunjukkan bahwa integrasi pendekatan pembelajaran berbasis masalah dengan teknologi AR dapat menjadi strategi inovatif dalam pembelajaran matematika untuk mendukung penguatan literasi numerasi siswa.*
Kata kunci*:* augmented reality*; literasi numerasi;* problem based learning

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Introduction

Numeracy literacy is an essential skill in the 21st century that is more than basic numeracy skills. Numeracy literacy skills are important to master because this ability requires students to not only perform calculation operations, but also be able to understand quantitative information, interpret data and use mathematical reasoning in solving problems which is often unstructured (Alimuddin et al., 2022; Astutik, 2022).Several studies show that many students at the junior high school level still experience difficulties when faced with non-routine, context-based questions or demanding deep interpretation (Astuti & Supiat, 2023; Myrela & Khuzaini, 2024; Syamsyiah & Handayani, 2023). Based on the results of the 2022 Programme for International Student Assessment (PISA), Indonesia ranks 72nd out of 81 participating countries. The mathematical literacy score of Indonesian students is 366 points, far from the international average score of 472 points. This score has decreased by 13 points from the 2018 PISA results, although the international average has also decreased by 21 points. From these results, only 18% of Indonesian students have reached at least level 2 proviciency in mathematics and almost none have reached the top performers category, namely reaching level 5 or 6 (OECD, 2023).

This low numeracy literacy is also reflected in the results of the Minimum Competency Assessment (AKM) in Indonesia. Studies show that Indonesian students tend to be able to solve routine procedural problems, but experience significant difficulties when faced with numeracy tasks that require data interpretation, mathematical representation, and problem-solving in real contexts (Dhini et al., 2024). Bolstad (2023) shows that numeracy literacy is related to math topics that occur in life, but classroom learning tends to emphasize theoretical mastery of the material. This suggests that students need to gain learning experiences that expose them to meaningful problems, data or information that must be interpreted, as well as encourage the functional use of mathematics in problems in everyday life.

One of the models that can support these needs is the Problem Based Learning (PBL) model. The PBL model places contextual problems as the starting point for learning so that students are encouraged to identify, formulate solutions, communicate results, and encourage students to learn actively in carrying out each step of the solution (Ayari et al., 2025; Tari et al., 2023). The results of the study Alashwal & Barham (2025) show that students who study with PBL show better problem-solving skills than traditional learning. The results of the meta-analysis by Paloloang et al., (2020) also show that the PBL model has a positive effect on numeracy literacy ability. This is in line with the results of research by Prihatiningtyas & Buyung (2023), and Wibowo et al., (2022) which show that the application of PBL can improve students' numeracy literacy skills compared to ordinary learning using the lecture method. Mathematics learning using an ethnomathematics-based PBL model can also help improve students' numeracy literacy skills (Nugroho et al., 2025).

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In addition to the learning model, the use of learning media also has the potential to strengthen students' learning experiences. One of the learning media that allows students to get a meaningful learning experience, directly faced with real visuals, is Augmented Reality (AR) technology. AR media helps students visualize and understand mathematical functions and increase knowledge and motivation to learn mathematics (Del Cerro Velázquez & Méndez, 2021; Vega et al., 2026; Zapata et al., 2024). AR media in learning not only functions as a complement to the media, but also as a means of representation that helps students connect contextual problems with mathematical models (Andrianu et al., 2025; Firdaus, 2021; Rahman et al., 2023).

Many studies have used PBL models and AR media, but AR media is used as an auxiliary medium in the PBL syntax stage, such as the research of Ekayogi (2023) which used AR media as an aid for spatial geometry material in learning with the PBL model. Then the observation results show that learning in schools has used PBL assisted by PPT media which only acts as a means of conveying a problem, so that there is no two-way interaction between learning media and students. In this study, PBL syntax is integrated into AR media where PBL steps are in AR media and students immediately get each stage of PBL syntax on the AR media. The purpose of this study is to analyze the significance of improving students' numeracy literacy skills by using PBL that is interacted in AR media.

Research Methods

Research Design

This study is a quantitative research using a one-group pretest-posttest design. In the design of this study, the researcher used one group as the subject of the study, so there is the potential for biased data from the influence of external factors. This is anticipated by making observations during the learning process. The learning process using AR media was carried out in 4 meetings, the first meeting was the implementation of *a pretest* to measure students' initial numeracy literacy skills before being given treatment. The second meeting was the implementation of learning with PBL integrated into AR media, the third meeting continued the learning process and the last meeting was the implementation of the posttest to measure the final ability of students after being given treatment.

Research Place and Subject

This research was conducted at Muhammadiyah Ahmad Dahlan Metro Junior High School. School selection is carried out based on the existence of a school policy that allows the use *of mobile phones* in classroom learning and supporting infrastructure. The subject of the study is one class VIII Ar-Rasyid with a total of 29 students. The sampling technique uses purposive sampling where the sample is selected based on certain considerations.

Data Collection Instruments and Techniques

The instrument used in this study is test questions. The questions used have elements of numeracy literacy with 4 questions with essays. Test instruments are used for *pretest* and *posttest* with the same questions. Before use, the questions were validated by 2 validators through a questionnaire sheet using the Likert scale. The

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validation results show that the questions are suitable for use without revision. Data collection techniques with pretest and posttest tests. Pretest scores as initial data on numeracy literacy skills before being given treatment, and *posttest* scores as numeracy literacy ability data after being given treatment.

Data Analysis Techniques

The data obtained from the pretest and posttest results were analyzed using quantitative analysis with the help of SPSS Statistics 25 software. The data was analyzed to determine the significance of differences in students' numeracy literacy skills before and after being given PBL learning integrated in AR media. The data analysis stage is normality test and non-parametric statistical test.

1. Normality Test

   The normality test is carried out with the aim of testing whether the data of *the results of the pretest* and *posttest of* students' numeracy literacy ability is distributed normally. The Normality Test is carried out before determining the statistical test as the basic assumption to conduct the next test. If the data is normally distributed, then a parametric test (T test) is used, but if the data is not normally distributed, a non-parametric test (Wilcoxon test) is used. The normality test was carried out using the Shapiro-Wilk test because the sample numbered relatively few or < 50. Based on the normality test, the data is considered to be normally distributed if the significance value (p-value) is greater than the predetermined significance level of 0.05 (sig. > 0.05)

2. Uji Wilcoxon

   The Wilcoxon test was carried out with the aim of testing whether there was a significant difference between students' numeracy literacy skills before being given treatment (pretest) and after being given treatment (posttest). Based on the results of the Wilcoxon test, if the value of sig. (2-tailed) less than 0.05 (sig. < 0.05), it can be concluded that there is a significant difference between the results of the pretest and the posttest. Or the zero (Ho) hypothesis in the study is rejected, this shows that learning with PBL integrated in AR has an effect on improving students' numeracy literacy skills.

Results and Discussion

This study uses a one group pretest-posttest design with a research sample of 29 students in grade VIII Ar-Rasyid of Muhammadiyah Ahmad Dahlan Metro Junior High School. Numeracy literacy ability data through pretest and posttest tests were collected and analyzed using the help of SPSS software with the normality test stages and the Wilcoxon Signed Ranks Test .

Descriptive statistical analysis of pretest and posttest of students' numeracy literacy ability is presented in Table 1.

Table 1. Descriptive Statistics of Pretest and Posttest

Variable	N	Average	Std. Deviation
Pretest	29	18.52	11.118
Posttest	29	68.72	16.377

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Based on Table 1, the average score of students' numeracy literacy ability increased from 18.52 in the *pretest* to 68.72 in *the posttest*. The standard deviation in the *pretest* was 11,118 and the standard deviation in the *posttest* was 16,337 indicating a wider variation in scores and the improvement of students' abilities was not homogeneous, this occurred because there was a difference in students' initial numeracy literacy skills. The data were then tested for normality as a condition for the parametric test using Shapiro-Wilk. The results of the normality test are presented in Table 2.

Table 2. Shapiro Wilk's Normality Test Results

	Statistic	**df**	**Sig.**
Pretest	0.943	29	0.112
Posttest	0.887	29	0.005

Based on Table 2, the Shapiro-Wilk significance value for the pretest of 0.112 is greater than 0.05 which shows that the pretest results are normally distributed. For posttest, the significance value was 0.005 < 0.05 which indicates that the data is not normally distributed. Because the posttest data is not normally distributed, then the data is analyzed using the Wilcoxon test. The results of the Wilcoxon Test are presented in Table 3.

Table 3. Wilcoxon Signed Ranks Test Results

	Posttest-Pretest
Z	-4.709
Significance (2-*Tailed*)	0.000

Based on Table 3, the significance value is 0.000 < 0.05 so that it can be concluded that there is a significant difference between students' numeracy literacy skills before and after being given learning with PBL integrated in AR.

The results of this finding can be influenced by the learning characteristics of PBL. In PBL learning, students are not directly given material procedurally but are faced with problems at the beginning of learning and guided to understand the problem. After understanding the problem, students are asked to discuss with the group to formulate the solution steps, choose a solution strategy and investigate the solution of the problem. After that, students develop and re-examine the results obtained, as well as present the results. This process is also in line with the essence of numeracy literacy which requires students not only to get answers immediately, but also to understand the context of the problem, interpret information and use mathematics as a way to solve it appropriately. Trigo (2024) states that a problem-solving-based learning environment encourages students to work with concrete, abstract, and symbolic representations so that it affects how they explore, reason, and solve problems.

At the stage of student orientation to the problem, the teacher provides students with contextual problems in AR media that require them to understand the situation of the problem, and determine what information is needed to formulate

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the solution. Research Kolar & Hodnik (2021) shows that students are more successful at solving contextual problems when they are able to recognize the mathematical content of the situation, and apply the knowledge to solve them. So that when learning starts from real problems, students are encouraged to enter the numeracy literacy process, namely understanding problems for the formulation of solutions.

At the stage of organizing students in groups, students begin to gather information and discuss what is known and asked about the information presented in the AR media. This stage strengthens numeracy literacy because students do not answer questions directly, but learn to arrange systematic thinking steps. (Wibowo et al., 2022) stated that students' activeness in learning affects numeracy skills, group discussions provide space for students to structure information and communicate students' ideas.

In the stage of guiding the investigation, students begin to select data, try strategies, connect the context with mathematical models, perform calculations and interpret provisional results. This stage represents a transition from understanding context to using mathematical concepts. After that, students learn to develop and present results at the stage of developing and presenting results. Students present the results in front of their peers, students need to explain the data used, the form of the mathematical model and the meaning of the answers. At this stage, it allows students to compare strategies and correct incorrect misunderstandings. Finally, namely the analysis and evaluation stage, students and teachers reflect on how to solve problems, this stage can strengthen numeracy skills because students not only execute procedurally but also demand that students can evaluate the results of their solutions.

In addition to the learning model, the use of AR media also helps in strengthening the learning process. The AR media used displays real problems using objects visualized in 3D. With the integration of PBL in AR media, students not only use it as an auxiliary tool, but PBL learning steps are found in the media. It also helps students improve their motivation to learn and live learning experience. Because basically, numeracy literacy requires the ability of students to move information from a real context to a mathematical form, and then return to interpret the results meaningfully.

Research conducted by Putri et al., (2025) shows that the use of AR media developed by researchers can improve numeracy literacy skills, but this study only uses AR media as a learning medium and does not use the PBL learning model. In this study, all PBL steps are in the AR media used, so that this AR media is used from the initial stage to the final stage of learning. The shortcoming in this study is that it has not involved a control group, so to measure the effectiveness of a stronger AR media, it is necessary to have a control group as a comparison. Furthermore, problem-based products can be developed for use in learning (Taulanita et al., 2026). Therefore, integrating AR media with the PBL model throughout the learning process has the potential to enhance numeracy literacy more effectively, although future studies should include a control group to obtain stronger evidence of its effectiveness.

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Conclusion and Suggestion

Based on the results of the research and discussion, it can be concluded that students' numeracy literacy skills using PBL integrated in AR media show a significant increase, as seen from the results of the Wilcoxon test with a significance value of < 0.05. Because this study used one group of samples without a comparison, subsequent research needed to conduct more robust experiments, a larger number of samples, and a more diverse range of mathematical topics in order to obtain more general evidence.

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