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Problem Based Learning Model with CRT Assisted by Augmented Reality to Improve Mathematics Learning Outcomes

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Abstract

In the 21st century, educational innovations are essential to enhance student engagement and the relevance of learning materials to their cultural and technological contexts. This study investigates the effectiveness of the Problem Based Learning model integrated with the Culturally Responsive Teaching approach, supported by Augmented Reality media, on the mathematics learning outcomes of fourth-grade students at Banjarejo Elementary School, specifically in the topic of flat shapes. It also compares the learning outcomes between classes utilizing this innovative model and those employing conventional teaching methods. Employing a quantitative approach with a Quasi-Experimental design, the study involved two classes: IV A as the experimental group (N = 20) and IV B as the control group (N = 20). Research instruments included validated and reliable multiple-choice and essay questions. The independent t-test analysis revealed significant differences in learning outcomes between the two groups. The findings indicate that the PBL model combined with CRT and AR is effective, achieving an N-Gain value of 58.45%. This approach fosters contextual, interactive learning that aligns with students, cultural backgrounds, demonstrating its potential to enhance educational practices in mathematics.

INTRODUCTION

Background of the Study

Education is a habit that plays an important role in life, because it not only gives us knowledge but also teaches us the right things. Education shapes character, builds mindsets, and becomes a foundation in facing various life challenges (Berlian et al., 2024; Jiang et al., 2025). However, education in Indonesia still faces various challenges, one of which is the low quality of student learning outcomes, especially in Mathematics (Harahap, 2023). Low interest in learning, lack of student involvement, and the use of monotonous learning methods are the main contributing factors. Therefore, one of the efforts that can be made is to apply innovative learning models that are able to develop critical thinking skills and motivate students to learn more effectively (Sari et al., 2022).

One of the learning models that can be used is Problem-Based Learning, which focuses on solving real or simulated problems that are relevant to students. Problem-Based Learning aims to develop critical thinking and problem-solving skills that are essential in the 21st century. The development of 21st century intelligence includes creativity, critical thinking, communication, collaboration, and life and career skills (Mulianti et al., 2023). This model emphasises active and independent learning, and can increase student learning motivation through meaningful problem solving (Pratiwi, 2022). The application of PBL is proven to improve student learning outcomes, especially in Mathematics subjects at the elementary school level, because students are directly involved in the contextual and relevant learning process (Utomo & Hardini, 2023).

Culturally Responsive Learning is an approach that recognises students' cultural backgrounds to create an inclusive and supportive learning environment (Hardiana, 2023). This approach can shape character, improve critical thinking, soft skills, and social and cultural awareness (Khalisah et al., 2023). CRT also connects learning materials with local culture thus increasing student motivation and participation. Research shows that implementing CRT in primary schools has a positive impact on learning motivation as students feel valued (Bostwick et al., 2025). This approach contributes to improving students' soft skills, socio-cultural awareness, and empathy. Current technological developments are increasingly sophisticated with the utilisation *of* web-based applications, one of which is Augmented Reality (AR) Technology to support learning.

Augmented Reality (AR) technology facilitates the visualisation of complex concepts, so that students can understand the material better and improve learning outcomes (Djafar & Novian, 2021; Sari et al., 2025). Learning using AR becomes more interactive and visual, increasing student engagement in understanding mathematical concepts (Fatasya et al., 2023). With this media, it is expected that teachers and students can collaborate effectively, achieving maximum learning outcomes, especially in mathematics. AR media combines the real world with digital elements in an interactive and real-time manner, allowing students to interact with digital objects. The use of AR media in learning mathematics can motivate students and make the learning process more fun and effective (Wulandari & Mawardi, 2013).

Learning outcomes are the main indicators of educational success that cover three domains, namely cognitive (knowledge), affective (attitude), and psychomotor (skills) (Hutapea, 2019). In learning Mathematics in elementary schools, student learning outcomes can be seen from an increase in understanding of concepts, ability to solve problems, and analysis and problem solving skills (Dhamayanti et al., 2024). Research shows that the use of active learning strategies, increased motivation, and the use of technology such as Augmented Reality (AR) can encourage the achievement of optimal learning outcomes (Suryadi, 2021). Learning motivation, both intrinsic (internal drive) and extrinsic (external influence), plays an important role in increasing student engagement and perseverance. Interactive learning methods such as AR are proven to trigger students' intrinsic motivation as they create interesting and challenging learning experiences. The teacher's role in designing creative and relevant learning also influences student learning outcomes. Therefore, the combination of Problem-Based Learning model, Culturally Responsive Teaching (CRT) approach, and *Augmented Reality* media is expected to be an innovative solution to improve Mathematics learning outcomes of elementary school students (Palyanti, 2023; Sobandi et al., 2021).

Problem of the Study

The learning system applied by teachers in Indonesia actually still relies on conventional methods (Hasriadi, 2022). Conventional learning models are no longer in accordance with the approaches applied today. In the 21st century, digital learning models should be used (Rahma et al., 2023). Conventional learning models are often applied by teachers using methods such as lecturing, answering questions, and giving assignments (Peranginangin et al., 2020).

According to observations and interviews with class teachers, the learning that has been applied at Banjarejo Primary School still uses conventional teacher-centred methods, such as lectures and assignments, so that it is less able to motivate and involve students optimally. This is shown by students' boredom and low enthusiasm during thQe learning process. In addition, limited technology-based learning facilities, such as the absence of LCDs, projectors and speakers in the classroom, as well as teachers' lack of ability to utilise digital learning media, also become obstacles in the application of innovative learning methods. Furthermore, the results of mathematics tests on flat shapes showed that only 42% of students reached the Minimum Completion Standard of 70, while the other 54% were still below this standard with low average scores. This condition illustrates the need to develop a more effective learning model that can improve student learning outcomes.

Research's State of the Art

Problem-based learning is an educational approach that places unstructured and realistic problems at the centre of the learning process (Sukerni, 2020). In line with this, Zainal (2022) states that PBL requires students to identify authentic problems, design solutions, and evaluate the problem-solving process. The steps in problem-based learning according to Hazima et al. (2024) include orienting students to the problem, organising students to learn, guiding individual or group experience, developing and presenting work, and analysing and evaluating the problem-solving process. The consistency of these steps is also expressed by Mardhani et al. (2022) which divides the PBL process into five main stages, namely problem introduction, research activity design, investigation assistance, facilitation of development and presentation of results, and process evaluation. Fariana (2017) also conveyed similar stages with an emphasis on guidance in investigation and evaluation of the progress of the problem-solving process. The advantage of PBL lies in its ability to significantly increase student learning activities, which can be observed through the stages of the learning cycle that show changes in student behaviour at each step (Dwindiarti et al., 2021). However, the success of PBL is highly dependent on the educator's ability to manage the classroom atmosphere and create an environment conducive to open interaction and exchange of ideas among learners (Lafendry, 2023 ; Rahmat, 2018). Rakhmawati (2021) adds that the weaknesses of PBL include limited educator guidance, the need for high resources in terms of cost and time, and the difficulty of teachers in monitoring student activities outside the classroom.

Culturally Responsive Teaching (CRT) is a teaching method that aims to strengthen learners' cultural identity and create a safe, inclusive and engaging learning environment. The main goal of CRT is to ensure that every student feels valued, actively involved, and has an equal opportunity to achieve academic success by accommodating their diverse cultural perspectives (Udmah et al., 2024). This is consistent with the opinion of Khalisah et al. (2023) which states that CRT-based teaching utilises students' cultural backgrounds, knowledge, experiences and learning styles to make the learning process more relevant and meaningful. CRT as an approach that emphasises the academic success of students from underrepresented backgrounds while maintaining their cultural identity (Rabia et al., 2024) . CRT implementation strategies according to Yoon et al. (2025) include creating a learning atmosphere that respects diversity, providing constructive feedback, turning mistakes into learning opportunities, and giving students freedom in controlling the learning process. This opinion is in line with Tarigan & Siskuntoro (2024) which argues that CRT is implemented through linking learning materials with learner culture, active participation and collaboration, diversity awareness, and cultural integration into learning activities. The advantages of CRT include improving learner learning outcomes, the effectiveness of material understanding, developing critical thinking skills, and creating an inclusive learning environment that respects cultural diversity (Darmayanti et al., 2022). However, CRT faces obstacles in the form of limited material that can be delivered and educators' challenges in adapting the material to diverse cultural backgrounds, which can result in a mismatch between the material and students' needs (Qothi & Khasanah, 2025).

Augmented Reality (AR) is a technology that incorporates two- or three-dimensional virtual objects into a real environment that is projected in real-time, so that users can interact with the environment interactively (Sara & Danawak, 2021). AR enriches the experience by adding digital information such as graphics, sound, and other sensory elements through devices such as smartphones and tablets (Sari et al., 2022; Qorimah et al., 2024). This technology is characterised by the merging of real and virtual worlds, real-time interactivity, and three-dimensional integration capabilities (Rojib & Ratnawati, 2024). In the context of education, AR expands the user's perception of an object and enables interactions that are not yet available in the real world while supporting a variety of devices as needed (Alfitriani et al., 2021). The advantages of AR include effectiveness as an experiential learning medium and contextual use that increases the relevance of learning materials to real conditions, thus significantly encouraging student learning outcomes (Carolina, 2022; Enjelina et al., 2024). Meanwhile, its disadvantages are dependence on specific hardware as well as high computational capacity for real-time data processing (Fatasya et al., 2023)

Gap Study and Objective

Research by Agusdianita et al. (2024); Dwindiarti et al. (2021); Theeuwes (2025) shows that problem-based-learning has an important role in improving student learning outcomes, especially in the context of education in Indonesia. This is supported by (Bostwick et al., 2025; Enjelina et al., 2024; Hardiana, 2023) regarding the application of Culturally Responsive Teaching in learning mathematics in elementary schools, especially related to student motivation and learning outcomes, is still limited.In addition, Alfitriani et al. (2021); Mulianti et al. (2023); Sari et al. (2022) mphasise that innovative learning media, such as augmented reality, can strengthen students' understanding of the material being taught. Although various studies show a positive relationship between Problem Based Learning, Augmented Reality media, and Culturally Responsive Teaching approaches, there is still a lack of research that links the integrated application of Problem Based Learning, technology utilisation, and culturally responsive learning approaches in an effort to improve student learning outcomes. Therefore, this study aims to examine the effect of applying the Problem Based Learning model combined with the Culturally Responsive Teaching approach assisted by Augmented Reality (AR) media in improving student learning outcomes, as well as analysing the differences in learning outcomes between students who use the model and students who follow conventional learning.

METHOD

Type and Design

This research uses a quantitative approach with an experimental research type. The experimental design applied was a quasi experimental design with a non-equivalent control group design, which is a design that compares two groups (experimental class and control class) without randomisation. This design is used to analyse the effect of a treatment on other variables in a situation that is not fully controlled.

This study aims to determine the effect of Problem Based Learning (PBL) learning model with Culturally Responsive Teaching (CRT) approach assisted by Augmented Reality (AR) media on mathematics learning outcomes of fourth grade elementary school students. The implementation of the study involved two classes, namely the experimental class that received treatment using the PBL model with the CRT approach assisted by AR media, and the control class that used the PAKEM model assisted by image media.

Both classes were given a pretest first to determine the initial ability. After that, each class received treatment according to the learning model and media used. Then a posttest was given to determine the improvement of student learning outcomes. The pretest and posttest scores were analysed to identify the effect of the treatment on the two variables studied.

Data and Data Sources

The sample for the study consisted of two classes of fourth grade students at Banjarejo Primary School. The experimental class had twenty students as samples and the control class had twenty students as samples. The control class used the conventional learning model, while the experimental class implemented the problem-based learning model using the Curturally Responsive Teaching (CRT) approach assisted by Augmented Reality (AR) media.

Data Collection Technique

This study uses quantitative data collection techniques that aim to measure the effect of Problem Based Learning (PBL) learning model with Culturally Responsive Teaching (CRT) approach assisted by Augmented Reality (AR) *media* on mathematics learning outcomes of fourth grade elementary school students. Data collection techniques used include giving pre-test and post-test instruments to measure student learning outcomes.

The pre-test and post-test instruments were prepared in the form of multiple choice questions and essays that were adjusted to the indicators of competency achievement in the mathematics curriculum at the primary school level. The pre-test was given to the experimental class and control class before the treatment was given, while the post-test was given after the treatment in each class was completed. The experimental class received treatment in the form of learning with the PBL model with CRT approach supported by AR media, while the control class received learning with the PAKEM model using image media.

The pre-test and post-test instruments were then tested for validity and reliability. The validity test of the instrument was tested on fifth grade students at Banjarejo Elementary School. The results of the instrument trial showed that 15 multiple-choice questions met the validity criteria, namely valid with a significance value> 0.444, while 5 questions were declared invalid. Therefore, multiple choice instruments that are declared valid will be used for research, while instruments that are declared invalid will be removed from the list of research instruments. Furthermore, the results of the validity of the essay question instrument show that 4 essay questions meet the validity criteria, namely valid with a significance value> 0.444, so that the essay question instrument will be used for research. After the validity test was carried out, then the multiple choice question instrument was tested for reliability. The reliability test is shown in Table 1 below.

Table 1. Reliability Test of Multiple Choice Question Instrument

Multiple Choice Question Instrument	
Cronbach's Alpha	N of Items
0,473	20

With an r-table value of 0.444, the results of measuring the reliability of the multiple-choice question instrument show a Cronbach's Alpha of 0.473 which indicates that the related instrument is declared reliable. Furthermore, the reliability test findings for the essay-shaped question instruments are shown in Table 2 below.

Table 2. Essay Question Instrument Reliability Test

Instrmen Soal Esai	
Cronbach's Alpha	N of Items
0,587	5

With an r-table value of 0.444, the results of measuring the reliability of the essay question instrument show Cronbach's Alpha of 0.587 which indicates that the instrument is reliable.

Data Analysis

Various baseline tests, including the homogeneity test and normality test were utilised in analysing the data. The normality test was conducted by applying the Kolmogorov-Smirnov test to evaluate whether the data followed a normal distribution, while the homogeneity test was analysed using the F test to determine whether the samples were homogeneous. The use of Augmented Reality *(AR)* interactive media combined with a problem-based learning model with a *Curturally Responsive Teaching* (CRT) approach was tested as a hypothesis to see its effectiveness on the learning outcomes of fourth grade elementary school students. The success of the learning model can be assessed through hypothesis testing using the N-Gain test and t-test which has a significance level of 0.05. All statistical analyses in the study were conducted using SPSS version 27 software.

1. Independen T-test

   The independent t-test is applied to analyse the difference in *mean* values of two unrelated groups of data. This test can be performed if the data has a normal and homogeneous distribution, although it is not always absolutely necessary. In this study, the data generated met the requirements for conducting an independent t-test. Thus, this test can be applied to test the hypothesis of experimental class *pre-test* and *post test* data with control class *pre-test* and *post test* data.
2. Dependent T-test

   The dependent t-test is required to determine the mean difference in two groups of interrelated data. This test was applied using the *pre-test* and *post-test* data of the experimental class.

3. Evaluate N-*gain*

   The N-gain calculation will be calculated using the Hake formula in (Febrinita, 2022).

$$N\text{-}gain\ (g) = \frac{Posttest\ Score - Pretest\ Score}{Maximum\ Score - Pretest\ Score}$$

Table 3. N-gain score effectiveness interpretation categories

Percentage	**Interpretation**
< 10%	Ineffective
10 – 29%	Less effective
30 – 69%	Effective
>70%	Very Effective

RESULTS

This study was conducted at Banjarejo Elementary School in March with the aim of knowing the effect of Problem Based Learning (PBL) learning model with Culturally Responsive Teaching (CRT) approach assisted by Augmented Reality (AR) media on mathematics learning outcomes of grade IV elementary school students. This study used a quasi-experimental design with a non-equivalent control group design, which involved two classes, namely class IV A as the experimental class and class IV B as the control class. Each class consisted of 20 students.

Before the treatment, both classes were given a pre-test to measure the initial ability of students in understanding flat building material. After that, the experimental class was given treatment in the form of learning using the PBL model with the CRT approach assisted by AR media, while the control class was taught using the PAKEM model with the help of image media. After the series of treatments were completed, both classes were given a post-test to measure the improvement of student learning outcomes. The results of the analysis showed that there was a significant increase in the value of the experimental class post-test results compared to the control class. The average gain score of the experimental class is in the high category, while the control class is in the low category. The *independent t-test* of the post-test results showed a significance value of $p < 0.05$, which means there is a significant difference between student learning outcomes in the experimental and control classes.

This study begins with the validity and reliability test of the instrument to ensure that the learning outcome test instrument is suitable for use. After that, the pre-test and post-test data were collected and analysed. Normality and homogeneity tests were carried out on data from both classes, namely experimental and control classes, to fulfil the requirements of parametric analysis. All statistical tests were conducted using SPSS software, see Table 4 in below to results:

Table 4. Normality test

	Class	A	Significance Value
Results	Control Pretest	0,05	.931
	Control Posttest	0,05	.621
	Pretest Experiment	0,05	.951
	Experiment Posttest	0,05	.621

The normality test results show that the significance value for the control class pre-test and post-test is 0.931 and 0.621, respectively. For the experimental class, the pre-test significance value was 0.951 and the post-test was 0.621. All significance values > 0.05, which means the data is normally distributed.

Table 5. Homogeneity test

	Test og Homogencity of Levene Statistic	df1	df2	Significance Value	α
Based on Mean	0,000	1	38	1,000	0,05

Based Table 5, the homogeneity test results show that the significance value based on the mean is 1.000 > 0.05, so it can be concluded that the data from both classes have homogeneous variance.

Table 6. Independent pre-test test of experimental learning outcomes compared to control pre-test

Sig (2-tailed)	α	t-value	Status
0,113	0,05	-1.621	$_{H0}$ Accepted

Based Table 6, Sig. (2-tailed) = 0.113 > 0.05, which means there is no significant difference between the initial learning outcomes of students in the experimental and control classes before the treatment is given.

Table 7. Independent t-test of experimental learning outcomes post-test compared to control post-test

Sig (2-tailed)	α	t-value	Status
0,001	0,05	-4.813	$_{H0}$ Rejected

Based Table 7, Sig. (2-tailed) = 0.001 <0.05, indicating a significant difference between student learning outcomes in experimental and control classes after treatment. Thus, the PBL model with the CRT approach assisted by AR media is proven to have a significant effect on the mathematics learning outcomes of grade IV students.

Table 8. Dependent t-test of experimental learning outcomes pre-test compared to post-test

Sig (2-tailed)	α	T-value	Status
0,001	0,05	-71.195	$_{H0}$ Rejected

Based Table 8, Sig value. (2-tailed) = 0.001 <0.05, indicating a significant increase in mathematics learning outcomes in experimental class students after applying the PBL model with the CRT approach assisted by AR media.

Table 9. N-Gain test of learning outcomes

Number of Students	Class	Average Post-Test Score	N-Gain (%)	Category
20	Experiment	78,4	58,45	Effective
	Control	61,95	27,04	Less Effective

Based on Table 9, the control class N-Gain test shows a value of 27.04% which indicates in the less effective category. Meanwhile, the experimental class N-Gain is 58.45% which indicates in the effective category. Therefore, the Problem Based Learning model with the CRT approach assisted by AR media is effective for improving student learning outcomes.

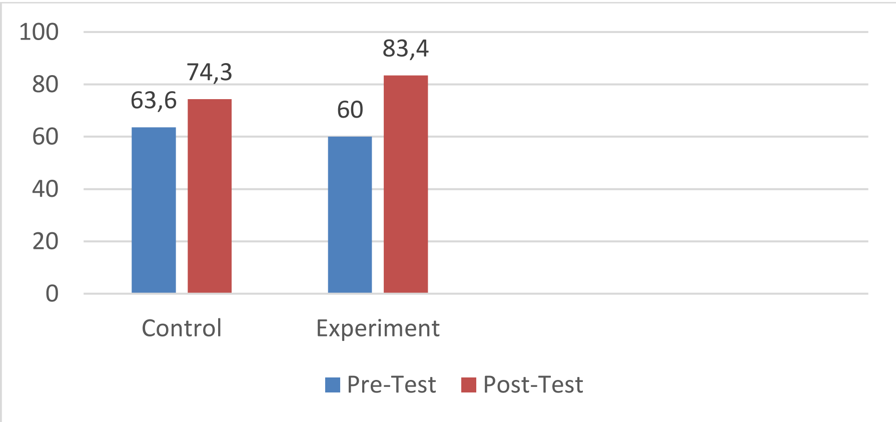

Figure 1. Average Learning Outcomes and Learning Motivation

Based Figure 1, the results of this study indicate that the Problem Based Learning learning model with a Culturally Responsive Teaching approach assisted by Augmented Reality media has a positive and significant effect on the mathematics learning outcomes of fourth grade elementary school students.

DISCUSSIONS

Learning models are methods or approaches applied by teachers in teaching a particular subject, with the aim of achieving predetermined learning (Polderdijk et al., 2025). The Problem Based Learning (PBL) model emphasises student involvement in finding solutions to real problems, thus honing students' thinking skills (Silvi et al., 2020). The learning model that has been used should be supported by the use of media in teaching and learning activities so that students' thinking skills can be further developed. Augmented Reality (AR) media makes it easier for students to understand lessons because it is able to present text, images, animations, audio, to three-dimensional visual objects that are interesting and interactive, thus increasing student focus and involvement in the learning process. In learning mathematics, the use of technology such as AR can strengthen the role of mathematics as a tool in the development of science, the formation of logical thinking patterns, and scientific attitudes (Ress, 2025; Sari et al., 2021). One of the materials that are suitable to be taught with AR media is flat shapes, because through 3D visualisation, students can see the shape, size, and differences between flat shapes more clearly and concretely, making it easier to understand concepts and their application in everyday life (Fernando et al., 2024; Sobandi et al., 2021).

Based on the results of research at Banjarejo Elementary School, this research was conducted from 24 February to 14 March 2025. Researchers conducted this research using several stages, namely giving questionnaires, pre-test and post-test. The pre-test was given to students with the aim of measuring their initial ability to mathematics material. The experimental class pre-test was given to students before implementing learning by applying Problem Based Learning, CRT approach assisted by AR media, while the control class pre-test was given to students before implementing a conventional learning model. The post-test for the experimental class was given after the application of the Problem Based Learning model with the CRT approach assisted by AR media, while the control class post-test was given to students after the application of conventional learning. Learning activities carried out in experimental and control classes begin with introductory, core, and closing activities.

The first stage includes introductory activities that begin by conveying apperceptions to connect new material with previous material followed by providing learning motivation through ice breaking to increase student enthusiasm before learning begins. The second stage is the core activities, starting with group formation, then playing interactive videos containing mathematical problem-based stories that can be accessed by scan-barcode. The purpose of providing interactive videos based on mathematical problems is to train students in analysing a problem that can encourage students to find solutions to problems or challenges given. This is also supported by Karimah et al. (2023) mathematics can be interpreted as part of all subjects that have an important role in education. The material of flat shapes is very relevant to everyday life, for example when measuring the surface area of a floor, calculating the need for tiles, or making designs of simple shapes. After that, a learning video is shown to increase students' understanding of the material and help students solve mathematical problems from the previous problem video. (See Figure 2 and Figure 3)

Figure 2. Video of Planar Geometry Problems **Figure 3.** Video of Planar Geometry Material

See Figure 4 to see the activity continued by observing Augmented Reality (AR) media that presents images to assess understanding and hone students' thinking skills. The use of AR media not only strengthens students' understanding of the material, but also increases the spirit of learning through interactive visual experiences (Resti et al., 2024; Wu et al., 2022).

Figure 4. Augmented Reality Media Platform

Next, students discuss to solve the problem in the video with the steps that have been listed on the student worksheet. Figure 5 shows, students make a simple mind map about flat building material. The last stage of this activity is giving practice questions to evaluate students' understanding of the material of flat shapes. Figure 6 shows the final stage is the closing of students and teachers together conclude the learning, provide feedback, and discuss follow-up. With the Problem Based Learning model that presents problems that aim to provide stimulation for students to learn so that it is hoped that learning will be more memorable and can find a solution to a problem (Hakam et al., 2022; Senja et al., 2024). This contributes to stimulating students' abilities and skills, and can improve student learning outcomes.

Figure 5. Students create mind mapping

Figure 6. Problem-solving discussion activity

There is a significant difference in student learning outcomes before applying the Problem Based Learning Model with the CRT approach assisted by AR media, compared to the conventional model assisted by media images. However, after applying the Problem Based Learning Model with the CRT approach assisted by AR media, there is a significant difference in student learning outcomes. This can be proven through the significance value (2-tailed) which is 0.001 <0.05 which shows an increase after applying the Problem Based Learning Model with the CRT approach assisted by AR media. The results of the N-Gain Test analysis show that the average of the experimental class is 58.45%, which shows that the Problem Based Learning Model with the CRT approach assisted by AR media is effective in improving student learning outcomes. The average value of the post-test showed different results, the experimental class reached 78.4, while the control class was only 61.95. This is corroborated by Siswanto et al., (2024) which shows that the application of the Problem Based Learning Model can improve student learning outcomes compared to the contextual model.

The Problem Based Learning (PBL) model is a learning model that emphasises student involvement in finding solutions to problems (Pramulia et al., 2025; Silvi et al., 2020). The advantages of the PBL model are that students become accustomed to facing and solving problems, both in class and in real life, this model encourages social solidarity through group and class discussions, strengthens teacher and student relationships, and trains students to apply the experimental method(Li et al., 2023; Rahmadani, 2017). One of the shortcomings of the PBL model according to Rachmawati et al. (2021) is learning preparation that requires complex tools, problems, and concepts. Such attractively designed teaching materials are likely to increase students' enthusiasm and motivation to learn, thus having a positive impact on their academic results (Agusdianita et al., 2024; Nadzeri et al., 2024). Augmented Reality (AR) media can be an effective alternative in supporting the technology-based learning process. AR allows students to interact directly with virtual objects in three-dimensional form, so that learning materials become more concrete and easy to understand. In the context of the Problem Based Learning (PBL) model, Augmented Reality (AR) media plays an important role in presenting problems visually and contextually, making it easier for students to identify problems and find solutions through active learning experiences. The main advantage of AR lies in its ability to deliver immersive and engaging learning, which not only increases learning motivation, but also strengthens understanding of abstract mathematical concepts. When integrated with the Culturally Responsive Teaching (CRT) approach, the use of AR in learning becomes more culturally relevant, as it is able to adapt content to students' backgrounds and experiences, making learning feel closer and more meaningful. However, the effectiveness of using AR is still influenced by infrastructure readiness, access to technological devices, and the competence of teachers and students in operating it (Arias Vilchez et al., 2024; Hidayat et al., 2025). Therefore, the successful implementation of AR media-assisted PBL in the CRT approach is highly dependent on the synergy between learning design, technological readiness, and students' cultural context.

CONCLUSION

This research was conducted by applying the Problem Based Learning model with the CRT approach assisted by AR media on learning outcomes in elementary school students in flat building teaching materials. By combining the Problem Based Learning model with the CRT approach assisted by AR media, this research provides novelty for students in participating in the stages of teaching and learning activities using approaches that have not previously been done. The findings of the study indicate that Problem Based Learning is able to support students in learning to overcome a problem that will improve student learning outcomes. Augmented Reality (AR) media applied to the Problem Based Learning Model is able to support students in actively participating in the learning stages and also encourages more enjoyable learning. This can deepen students' understanding of the material, which leads to an increase in student learning outcomes. The limitations of the study are that the implementation of Augmented Reality (AR) media requires adequate devices and stable internet access. In conditions where the device or internet network is limited, especially in classroom IV which is located in the farthest room from the wifi network with minimal access to technology, the use of this media can be a barrier. Further research could evaluate whether the impact of the PBL model with the CRT approach aided by AR media on student learning outcomes persists in the long term and see how these skills develop at the next level of education in different subjects and grade levels. This study has suggestions that teachers need to design more interactive learning to strengthen students' understanding of the material. Teachers as educators can also implement problem-based learning models with the CRT approach assisted by Augmented Reality (AR) media in the classroom on the material to be taught. Learning can be done by applying the Problem Based Learning model with a CRT approach assisted by AR media that will improve student learning outcomes, motivate students to be active when learning and encourage students to learn to analyse a problem. And with the use of Augmented Reality (AR) media, learning becomes more fun because it is game-based.

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