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Integrating virtual reality and problem-based learning in STEM education: A contextual approach to enhance mathematical literacy through cultural heritage

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Abstract

Mathematical literacy is an essential competency in mathematics education that plays a crucial role in equipping students to meet the demands of the 21st century. However, students' mathematical literacy in Indonesia remains low. This study aimed to investigate how problem-based learning (PBL) with virtual reality (VR) technology in STEM education, contextualised within the complex of Arjuna Temple in Dieng, could be designed to enhance mathematical literacy. The study employed a design research method involving tenth-grade students at a senior high school in Wonosobo, Indonesia. Qualitative techniques were used to analyse students' responses to the implemented learning, while quantitative techniques were applied to analyse students' pretest and posttest results. The study produced a learning design validated by three experts and deemed practical by five practitioners. The results indicated a significant improvement in students' pre- and post-test scores. Students also provided positive feedback regarding the developed learning program. Given these results, Problem-Based Learning with Virtual Reality STEM education technology contextualised to the Arjuna Dieng Temple complex was considered a viable approach to enhancing mathematical literacy.

Keywords: mathematical literacy; problem-based learning; STEM; virtual reality

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Introduction

The 21st century is synonymous with the rapid development of digitalisation, where technology is increasingly used in various fields, including education, and is now an integral part of the learning process. In the 21st century, competencies such as critical thinking skills, collaboration, communication, and creativity are crucial (UNESCO, 2017). 21st century education focuses on developing the ability to think critically, relate science to life problems, master technology, and have the skills to collaborate and communicate effectively (Dare et al., 2021). Literacy skills are one of the prerequisites for students to develop the demands of 21st century ability (Gündüzalp, 2021). One of the abilities that can be developed in mathematics learning is mathematical literacy, which is very important in equipping students with the skills needed to face the demands of the abilities that must be achieved in the 21st century (Sujatha & Vinayakan, 2022).

Mathematical literacy is a person's ability to utilise mathematics to solve real-life problems, including the ability to think mathematically, formulate, apply, and understand how to solve problems in various real-world situations (Çakıroğlu et al., 2024). Mathematical literacy is a skill and knowledge that is not only useful for meeting financial needs but also plays an important role in self-development in the social, economic, and cultural fields of modern life (Hamidah et al., 2024). However, in reality, Indonesia's mathematical literacy level is still relatively low and even tends to decrease from the previous year. Although Indonesia experienced a five-rank increase in the Program for International Student Assessment (PISA) 2022 results compared to the PISA 2018 results, Indonesia's average mathematical literacy score actually decreased by 13 points, from 379 in the PISA 2018 results to 366 in the PISA 2022 results, with a percentage reaching level 2. (OECD, 2023; Situmorang, 2024).

Mathematical literacy among students in Indonesia, including in the Wonosobo region, remains very low. Based on interviews with several mathematics teachers at a high school in Wonosobo, it was revealed that students still struggled with critical and systematic thinking when solving contextual problems. This leads to difficulties in addressing more complex issues, which ultimately impacts their mathematical literacy skills (Nurva et al., 2022). This concern was supported by the results of an initial test administered to measure students' mathematical literacy levels at the school, which yielded an average score of 37.72 out of 100.

The development of students' mathematical literacy requires a learning model that can encourage students to solve problems related to real life. One of the learning models that can improve students' mathematical literacy is Problem-based Learning (PBL) (Tabun et al., 2020). Problem-based Learning (PBL) is a learning model that uses contextual problems to encourage students to solve real-life challenges (Tabun et al., 2020). PBL aims to encourage students to learn actively; through problems, students are challenged to explore curiosity and curiosity, develop higher-order thinking skills, and through active discussions, students can identify problems, make hypotheses, and solve problems (Juandi, 2021). PBL can have a positive and significant impact on improving students' mathematical literacy (Syafitri et al., 2021).

PBL combined with learning media can create a more conducive and effective learning environment (Yasin & Novaliyosi, 2023). One of the utilisations of technology-based learning media is Virtual Reality media. Virtual Reality (VR) is a computer simulation technology that creates a three-dimensional environment that appears real to its users (Christopoulos et al., 2020). The initial goal of this technology was to create a movie-viewing experience that feels real by involving various senses, namely sight, hearing, smell, and touch (Moch & Akhsani, 2020). One of the advantages of Virtual Reality (VR) is its ability to create an interactive learning environment and provide learning experiences that support students' abstract thinking and communication (Marougkas et al., 2023). This shows that VR media can be combined with PBL learning, where VR can provide an overview to students related to the problems given as if they were real.

Improving students' mathematical literacy also requires an approach that encourages them to understand concepts thoroughly and apply them in real-world contexts. One learning approach that can improve students' mathematical literacy is the Science, Technology, Engineering, and Mathematics (STEM) approach, which helps students improve their mathematical literacy skills (Dewi & Maulida, 2023). The STEM approach is an interdisciplinary approach to learning where students use science, technology, engineering, and mathematics in real contexts that connect schools, the world of work, and the global world to develop literacy that enables students to compete in the new knowledge economy (Kelana et al., 2020). Learning design is significantly carried out through student activities that involve developing the skills and knowledge they possess. In this context, the STEM field offers many opportunities for students to engage in in-depth mathematical investigations that encompass various other disciplines (Forde et al., 2023).

As time progresses, mathematics education can utilise learning resources from diverse cultures (Pathuddin & Nawawi, 2021). One such resource is the Arjuna Temple Complex, which reflects the integration of history, architecture, ancient technology and cultural science. With a STEM approach, this complex can serve as an ideal meeting point for presenting real-world problems that require critical and collaborative thinking across disciplines and fields. For example, the structural calculations of temple buildings can be studied within the context of science and mathematics. Integrating knowledge through landmarks is an engaging strategy for mathematics education (Nugroho et al., 2024). Mathematics education that integrates local cultural contexts plays a crucial role in making the material more relevant and meaningful for students (Harefa & Suastra, 2024). By connecting mathematical concepts with local culture, a more relevant and meaningful context can be created, enabling students to understand the practical application of mathematics in their daily lives (Mania & Alam, 2021).

The integration of the PBL model with Virtual Reality STEM education technology in the context of the Arjuna Dieng Temple complex is a novelty in this research. Integrating Virtual Reality in learning can be a new and unique way to improve students' mathematical literacy. The question in this study is how problem-based learning with virtual reality STEM education technology in the context of the Arjuna temple complex can be designed to improve mathematical literacy.

Methods

This study used a design research approach because this method was appropriate for the research conducted, which placed the design of new educational materials, such as learning activities and computer-based tools, as an essential element in the overall research process (Bakker, 2018). The research question was an extension of previous research on Virtual Reality STEM Trails (Cahyono, 2024). The design research process consisted of three stages: preparation and design, teaching experiment, and retrospective analysis (Bakker, 2018). The preparation and design stage involved formulating initial design principles, developing an initial hypothesis map, and creating an initial design of the Hypothetical Learning Trajectory (HLT). In the teaching experiment stage, the researcher implemented the designed learning activities in the classroom. In the retrospective analysis stage, the researcher compared the HLT with data on the actual learning experienced by students while performing various tasks and analysed improvements in students' mathematical literacy.

This study was conducted in Wonosobo, Indonesia, involving a local high school. The research began with initial interviews with teachers to assess the curriculum, student needs and characteristics, and the learning environment. The next step was to conduct observations at the Arjuna Dieng Temple complex to analyse the appropriate learning content. The third step was design, where the researcher designed the learning media (VR STEM education link) and learning activities, which were then tested on five students in a small group. The next step was to develop media and learning activities for field testing.

Grade X13 was the class used in this study, consisting of 33 students (11 male and 22 female). The sample was selected based on the suitability of student characteristics to the research focus, such as educational level and exposure to the local cultural context or specific learning materials. As this study examined mathematics learning using VR in a local cultural context, high school students living in culturally rich areas were considered an appropriate sample. Class selection was performed using cluster random sampling from the 13 existing classes. The researcher administered tests to measure students' mathematical literacy before (pretest) and after (posttest) participating in PBL-assisted VR STEM learning. The research instruments included pre- and post-test questions aligned with mathematical literacy indicators, as well as a student response questionnaire. The mathematical literacy indicators used involved systematically formulating problems, applying mathematical concepts, facts, procedures, and reasoning, and interpreting, applying, and evaluating mathematical results (Agustiani et al., 2021).

Data collection techniques were implemented through interviews, response questionnaires, and mathematical literacy tests. The student response questionnaire consisted of ten statements covering indicators such as media operation, media quality, benefits, learning interest, and media display. The student mathematical literacy test consisted of three questions representing three indicators of mathematical literacy: The mathematical literacy test questions were first tested for validity and reliability. The validity test yielded an r-value for each question: for question 1, for question 2, and for question 3. Therefore, it was concluded that the three test questions were valid and reliable. The reliability test yielded a calculated r-value of, indicating that the mathematical literacy test questions were reliable. The pretest and posttest data collected by the researcher were analysed to determine the improvement in students' mathematical literacy after participating in Problem-Based Learning using VR STEM education technology within the context of the Arjuna Dieng Temple complex in the topic of trigonometric comparison. The research instrument was validated by a mathematics lecturer as a media expert and two mathematics teachers as subject matter experts and practitioners. A practicality test was conducted on a small group before implementation in the experimental group.

Data analysis was conducted using both qualitative and quantitative techniques. Qualitative techniques were used to analyse student response questionnaires after they participated in problem-based learning integrated with VR STEM education technology in the context of the Arjuna Dieng Temple complex. This technique was implemented by analysing the interview results and student responses. Quantitative techniques were employed to analyse mathematical literacy based on students' pretest and posttest results. The researcher applied a paired t-test to determine whether there was a significant difference between the students' pre- and post-test scores. Subsequently, an N-Gain Score analysis was conducted to determine the extent of improvement in students' mathematical literacy.

Results

The research results were presented in three main aspects that described the stages of design research, namely the design of PBL integrated with VR STEM education technology in the context of the Arjuna Dieng Temple complex, teaching experiments, and retrospective analysis.

PBL design with VR STEM education technology in the context of the Arjuna Dieng Temple complex

The first stage was observation and interviews with mathematics teachers at a final secondary school in Wonosobo, which revealed that the school implemented the Merdeka Curriculum. Students were found to prefer interactive and group learning over the lecture method. Their learning environment was also considered strategic and supportive of enhancing learning interest, as students demonstrated a high level of curiosity toward new things. However, many of them expressed a dislike for mathematics, particularly when it was taught using the lecture method. Additionally, the school's facilities and infrastructure already supported the use of virtual reality, including the use of smartphones for learning activities that required such technology.

The next stage was designing the VR Arjuna Temple Complex, which began with observing the Arjuna Dieng Temple complex to analyze in detail the objects and develop the VR plan using a 360 camera. After the observation, the researchers determined the temples to be used as VR content for learning and edited the 360° images using Adobe Photoshop CC 2018. The VR design was carried out by inserting the edited 360° images into the VR content using the website https://theasys.io, as shown in Figure 1. In VR mode, an arrow button was added to allow users to move to the next location by pointing the VR center point at the button for three seconds, as illustrated in Figure 2.

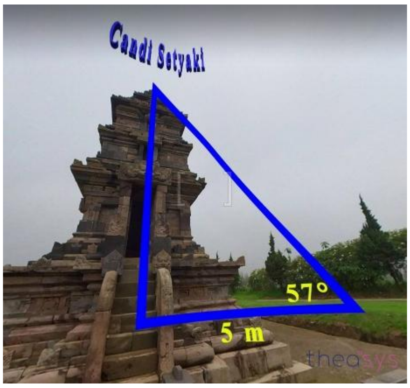


Figure 1. Display in VR

Figure 2. VR mode and location switch button

In this study, the development of VR STEM education was carried out by selecting the Problem-Based Learning (PBL) model with VR STEM education technology contextualized to the Arjuna Dieng Temple complex. The PBL model was chosen because it allowed students to be more active in the learning process, collaborate, and develop the necessary skills (Khairani et al., 2020). Learning was conducted in accordance with the existing PBL syntax, namely: meeting the problem, problem analysis and learning issues, discovery and reporting, solution presentation and reflection, and overview interaction and evaluation. After the learning model was determined, the researcher created links to be used by students to access the VR content. The VR links for each session were as follows: first meeting https://bit.ly/CandiArjunaTour1, second meeting https://bit.ly/CandiArjunaTour2, and third meeting https://bit.ly/CandiArjunaTour3.

Before being used in teaching, the PBL design with VR STEM education technology in the context of the Arjuna Dieng Temple complex was first tested for validity and practicality. The validity test was carried out by three validators, namely media experts, material experts, and learning experts. Based on the results of the validity test, a score of 94.29 was obtained from media experts, 91.33 from material experts, and 90 from learning experts. The practicality test was conducted through small-group trials involving five participants, yielding an average score of 81.6 out of 100. These results indicated that the validity and practicality of the PBL design with VR STEM education technology in the context of the Arjuna Dieng Temple complex were in the very high category and were deemed suitable for use in learning.

Teaching experiment

Problem-based learning combined with VR STEM education technology in the context of the Arjuna Dieng Temple complex was applied to grade X13 at a high school in Wonosobo, Indonesia. Before the learning began, students were given a pretest to measure their initial ability to solve mathematical literacy problems related to trigonometric comparison. The pretest results showed that the average student score was 51.03 out of 100, with the lowest score being 39 and the highest score being 61.

The learning process involved 33 students who were divided into 8 groups, with each group consisting of 4 to 5 students. The learning activities were conducted over 6 lessons across 3 meetings, following the PBL syntax in each session. The learning activities carried out in each meeting were generally similar, differing only in the material covered. In the first session, students studied topics related to the conversion of angles between radians and degrees. In the second session, they learned about the trigonometric ratios of sine and cosine in right triangles. In the third session, the focus was on the tangent ratio in right triangles. At the beginning of the learning process, students were introduced to the learning media supported by virtual reality, which was used throughout the sessions. The lessons began with the teacher presenting a contextual problem related to trigonometric ratios, which students then observed and analyzed. The problem and its relevant information were delivered through virtual reality during the problem analysis and learning issue phase, as well as during the discovery and reporting phase. At the end of each lesson, students presented their group discussion results to the class and received feedback from their peers. The students' learning activities were illustrated in Figure 3.

Figure 3. Student learning activities

After participating in learning using the Problem-Based Learning model with Virtual Reality STEM education technology in the context of the Arjuna Dieng Temple complex, students were given a posttest to measure their final ability to solve mathematical literacy problems on trigonometric comparison material. Based on the posttest results, the average student score was 80.91 out of 100, with the lowest score being 70 and the highest score being 96. The comparison results between pretest and posttest scores were presented in Figure 4.

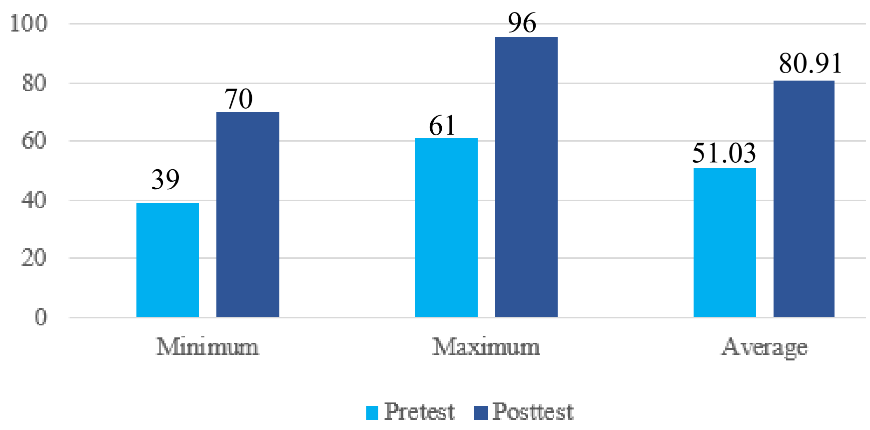
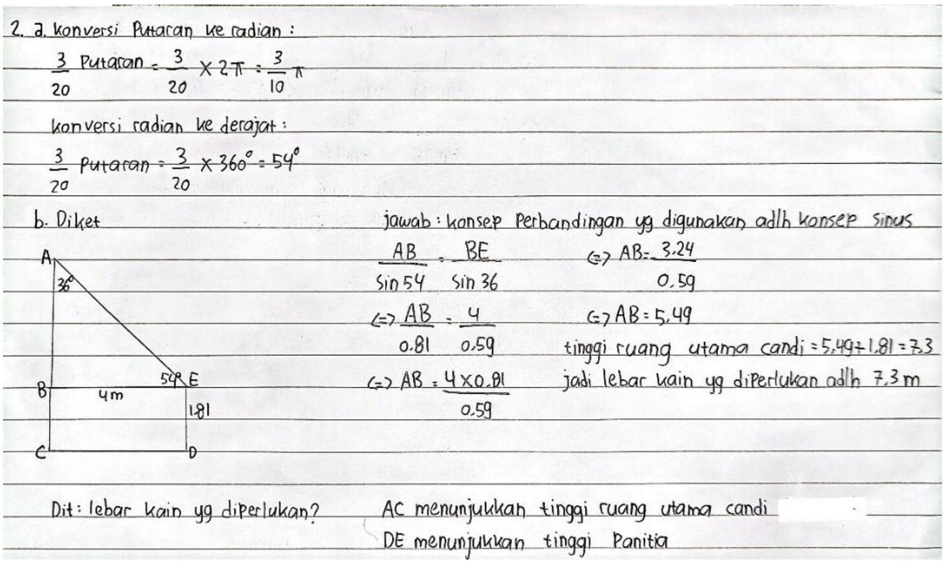


Figure 4. Comparison of pre- and post-test results

In the teaching experiment process, students were given a series of test questions to assess their mathematical literacy skills. One of the results of a student's work on problems related to trigonometric comparison material was as follows. In the problem, the distance between a person and Arjuna Temple was stated as 4 meters, the person's elevation angle with the top of the main room of the temple was $\frac{3}{20}$ rotation, and the person's height was 181 cm. In this problem, students were asked to determine the elevation angle in radians and degrees, and then calculate the height of the white cloth needed to cover the main room of the temple. The results of the student's work were assessed based on mathematical literacy indicators.



Translation
a. Conversion from rotations to radians: $\frac{3}{20}$ rotation $= \frac{3}{20} \times 2\pi = \frac{3}{10}\pi$
Conversion from rotations to degrees: $\frac{3}{20}$ rotation $= \frac{3}{20} \times 360° = 54°$
b. It is known: AC indicates the height of the main chamber of the temple.
DE DE indicates the height of the committee.

Asked: What is the required fabric width?

Answer: The comparison concept used is the sine concept.

$$\frac{AB}{\sin 54} = \frac{BE}{\sin 36} \Leftrightarrow \frac{AB}{0.81} = \frac{4}{0.59} \Leftrightarrow AB = \frac{4 \times 0.81}{0.59} \Leftrightarrow AB = \frac{3.24}{0.59} \Leftrightarrow AB = 5.49$$

height of the main chamber of the temple$= 5.49 + 1.81 = 7.3$

So, the required fabric width is 7.3 m

Figure 5. Example of student work

Figure 5 shows that students identified problems and formulated them into mathematical forms using right triangle diagrams. This aligned with the indicator of systematically formulating problems, which was assessed based on whether students contextualized the problems into mathematical representations. Indicators of using mathematical concepts, facts, procedures, and reasoning were assessed based on the correctness of students' answers in applying the concepts they had learned. Students used the concept of sine ratios to calculate the height of a triangle, resulting in a value of 5.59 meters. Indicators of interpreting, applying, and evaluating results were assessed by whether students drew conclusions that were connected to the original problem situation. In Figure 5, students concluded that the height of the main room of the temple was 7.3 meters, which they then related to the context of the Arjuna Temple problem.

Data from students' pretest and posttest results were analyzed using statistical testing to determine the improvement in students' mathematical literacy. A normality test was first conducted on the students' pretest and posttest data. Based on the test, the pretest Sig. was $0.200 > 0.05$ and the posttest Sig. was $0.191 > 0.05$, so it was concluded that the students' pretest and posttest data were normally distributed. The data were then tested using a paired sample t-test, which showed a Sig. (2-tailed) value of $0.00 < 0.05$, indicating a significant difference in the average student learning outcomes before and after the learning process, as shown in **Table 1**. Based on these results, it was concluded that the Problem-based Learning design with VR STEM education technology in the context of the Arjuna Dieng Temple complex improved students' mathematical literacy.

Table 1. Paired sample t-test

Paired Samples Statistics					
		Mean	**N**	**Std. Deviation**	**Std. Error Mean**
Pair 1	Pre-test	51.03	33	5.913	1.029
	Post-test	80.91	33	7.002	1.219

Paired Samples Correlations				
		N	**Correlation**	**Sig.**
Pair 1	Pre- & Post-test	33	0.171	0.342

Paired Samples Test									
		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	**Std. Deviation**	**Std. Error Mean**	**Lower**	**Upper**	**t**	**df**	**Sig. (2-tailed)**
Pair 1	Pretest - Posttest	−29.88	8.358	1.455	−32.84	−26.92	−20.54	32	.000

The analysis of mathematical literacy improvement was conducted using the N-Gain score. The data used consisted of pretest and posttest scores from mathematical literacy tests administered before and after the students were treated with PBL combined with Virtual Reality STEM education technology in the context of the Arjuna Dieng Temple complex. Based on the calculation, the average N-gain score was found to be 0.643. This result indicated that the average improvement in students' mathematical literacy through PBL with Virtual Reality STEM education technology in the context of the Arjuna Dieng Temple complex fell into the medium category.

Student response questionnaire

After the implementation of Problem-based Learning with VR STEM technology, students were given a questionnaire to determine their responses to the learning process. The purpose of completing the questionnaire was to identify and measure the level of student satisfaction after the learning activities. This aligned with the statement by Baherimoghadam et al. (2021) who noted that one way to assess student satisfaction after learning is through the use of a student response questionnaire. Five aspects were measured in the response questionnaire: media quality, media operation, benefits, interest in learning, and learning support, with the results presented in Figure 6.

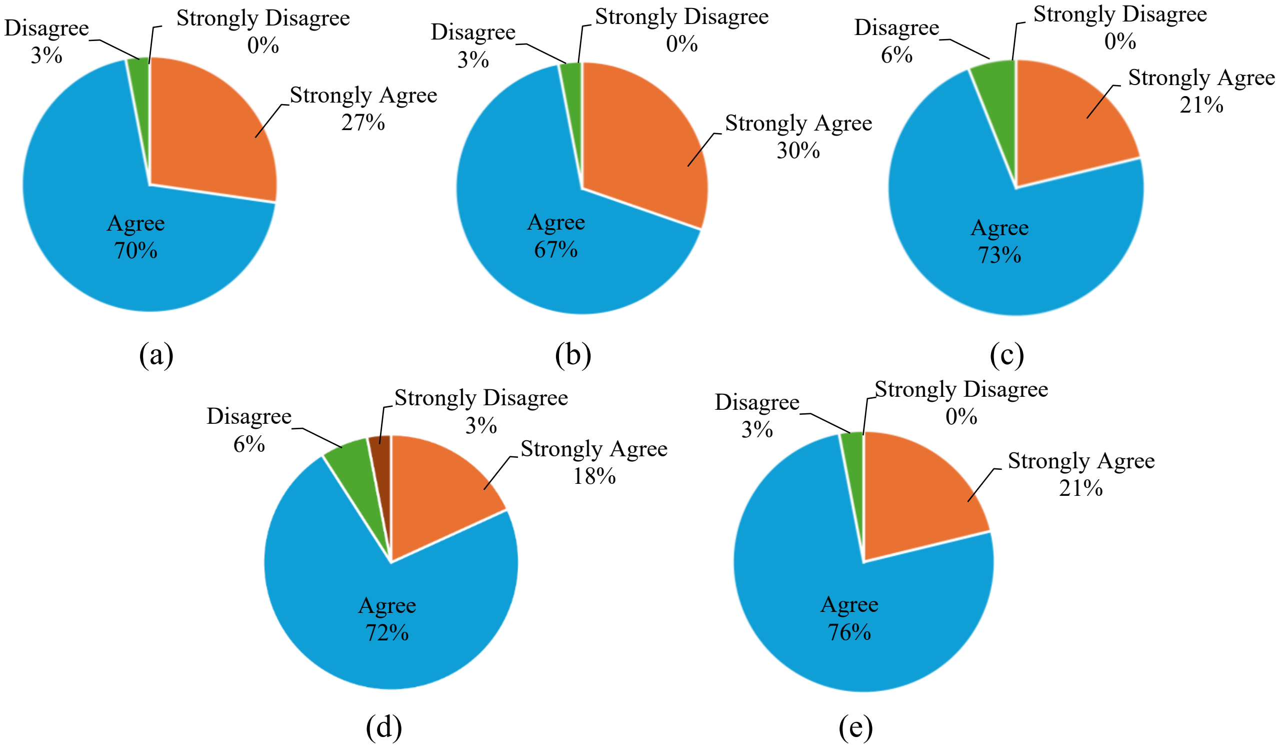


Figure 6. The results of the student response questionnaire regarding problem-based learning with STEM education virtual reality technology in the context of the Arjuna Dieng Temple complex were analyzed from the aspects of (a) media operation, (b) media quality, (c) benefits, (d) learning interest, and (e) display

Based on Figure 6, the development in this study received a positive response. In the aspect of media operation, 70% of students agreed and 27% of students strongly agreed that the learning media was easy to operate and could be accessed practically during learning activities. In terms of media quality, 67% of students agreed and 30% strongly agreed that the media helped them understand the material and solve mathematical problems through visualization of real situations using VR. Regarding the benefits, 73% of students agreed and 21% strongly agreed that the media provided new insights and learning experiences. From the aspect of learning interest, 72% of students agreed and 18% strongly agreed that their interest and motivation in learning mathematics had increased. In terms of display, 76% of students agreed and 21% strongly agreed that the learning media had a very attractive appearance. The results of the student response questionnaire showed that the implementation of PBL with VR STEM education technology in the context of the Arjuna Dieng Temple complex supported the learning process, increased learning enthusiasm, and reduced boredom in learning mathematics.

The response results were supported by the findings of interviews with several students who stated that, at first, they thought the VR STEM Education media would be difficult to use. However, after trying it directly, they actually felt that the media was easy to operate and had a very attractive appearance. Other students also revealed that the use of this technology was able to increase their interest in learning mathematics because it was new and different from the usual learning methods they received at school. The uniqueness and interactivity of the VR media provided a more enjoyable and in-depth learning experience for students. Therefore, it was expected that the use of this media could optimally contribute to improving students' mathematical literacy.

Discussion

The validation process aimed to assess the feasibility of PBL VR STEM Education based on the Arjuna Dieng Temple Complex before it was used in learning. The validation was carried out by three experts: a media expert, a material expert, and a learning expert. The validation results showed that the media and material aspects were highly valid; thus, the learning tool was declared feasible for use. The validation and evaluation conducted indicated that this learning tool could be applied to the learning process (Fernandes & Syarifuddin, 2020). This finding aligns with the research by Fernandes and Syarifuddin (2020), who stated that validated tools could be implemented in the learning process.

The practicality of PBL with VR STEM Education based on the Arjuna Dieng Temple Complex was evaluated through a questionnaire completed by five students after participating in the learning process using this medium. The results indicate that the learning tool is highly practical, covering aspects such as media operation, quality, visual appearance, learning interest, and benefits as instructional support. Media that were easy to use, of high quality, and visually appealing were considered capable of enhancing students' understanding and interest in learning. Moreover, the interactive and contextual approach of the media enriched the learning experience and was relevant to students' daily lives (Nurfadhillah et al., 2021). The practical learning tool was deemed suitable for implementation in classroom instruction (see Ruiz-Rojas et al., 2023). These findings are consistent with those of Tanjung and Nababan

(2018), who demonstrated that practical learning tools could be effectively implemented in educational settings.

The Problem-Based Learning model with Virtual Reality STEM education technology contextualised within the Arjuna Dieng Temple Complex was able to improve students' mathematical literacy. This was based on the results of statistical testing, which showed an N-Gain score of 0.643, indicating a significant improvement between students' pre- and post-test scores. The implementation of the Problem-Based Learning model helped create a more effective mathematics learning experience for students. In line with the view that problem-solving in real-world contexts can enhance students' active participation, this method allowed them to understand mathematical concepts and skills more deeply (Üredi & Doğanay, 2023). In the field of education, the use of technology has enhanced students' mathematical literacy by promoting independent learning and providing a fresher, more interactive learning experience (Tambunan & Mukhtar, 2023). VR visualisation can provide a sensation for students as if they are in the location directly, which can better support students' interest in learning mathematics.

The VR STEM education developed supports students' learning needs with varied media, helping them understand the material better and solve problems in a real-world context. Thus, students' mathematical literacy can increase because mathematical literacy includes the ability to understand and use mathematics to solve problems in real-world contexts (Pratama, 2020). The improvement of mathematical literacy can also be observed through the completion of problem exercises by students, which have met the indicators of mathematical literacy, both on questions in VR and on pretests and posttests that have been aligned with mathematical literacy indicators. Students can appropriately formulate contextualised problems into mathematical forms, apply concepts to perform calculations with the correct steps, and draw conclusions from the results of their work. The results of student work from questions that cover all indicators of mathematical literacy can be used to measure students' mathematical literacy (Maslihah et al., 2021). In VR-based STEM education, VR technology plays a role in increasing accessibility, effectiveness, and efficiency in learning, which contributes to improving students' mathematical literacy. In research related to the influence of VR technology in education, the utilisation of VR technology can support the increase of students' active involvement, motivate them in learning, and strengthen their mathematical literacy (Buchori & Rahmawati, 2024; Çakıroğlu et al., 2024).

The STEM education context uses temple objects, technology, and the unique architecture of the temples in the Arjuna Temple complex. The objects chosen are those that can provide an overview for students about the temple to analyse how to determine the size of the temple using trigonometric comparison. STEM provides learning experiences that connect various disciplines and applications in real life, where students learn not only mathematics but also other fields through various problems presented (Wan et al., 2020). The problems in VR STEM education link the temple context with the learning environment in the classroom and apply practical applications through VR technology, allowing students to develop knowledge independently. This is in line with research by Hacioglu and Gulhan (2021), who stated that the STEM approach is effective in developing students' way of thinking through various perspectives of knowledge and examples around them, allowing them to build knowledge independently.

The development in this study received positive feedback from the students. This is indicated by students' responses after participating in learning with Problem-based Learning with VR STEM education technology in the context of the Arjuna Dieng Temple complex which has a positive impact and effective learning for students and increases students' mathematical literacy. In line with this, students' positive responses to learning can facilitate the understanding of learning materials and make the learning process more interesting, which ultimately contributes to the improvement of their cognitive abilities (Amalia et al., 2022; Kusuma et al., 2022). Therefore, PBL with VR STEM education technology in the context of the Arjuna Dieng Temple complex can be developed for students.

Conclusion

The Problem-based Learning with Virtual Reality STEM education technology in the context of the Arjuna Dieng Temple complex can be designed to improve students' mathematical literacy. This is indicated by the acquisition of results in the form of Problem-based Learning with Virtual Reality STEM education technology in the context of the Arjuna Dieng Temple complex which is valid and practical, and there is an increase in students mathematical literacy of 0.643 which is in the moderate category. This is reinforced by student responses that give positive responses to the development carried out as measured from five aspects, namely media quality, media operation, benefits, learning interest, and media display, and an increase in interest in learning mathematics. However, the improvement in mathematical literacy varies depending on moderating factors such as learning style, prior knowledge, and characteristics of high school students. In addition, this study is limited to one local cultural context; therefore, the results cannot be widely generalised without further research in different contexts.

Researchers have suggested that teachers integrate Problem-based Learning with virtual reality media in mathematics learning to help the student learning process. Integration is also done on materials that are not only related to trigonometry and on other cultural objects to introduce cultural diversity to students. Similar research can also be conducted by applying PBL with VR STEM education technology to other students' cognitive abilities with other cultural objects.

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Conflicts of Interest

In writing this manuscript, the authors declare no conflict of interest. Furthermore, ethical issues, violations, plagiarism, falsification and/or fabrication of data, double publishing, and redundancy have been resolved by the authors.

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