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# Project-based learning through augmented reality-assisted math trails at Blenduk Church to promote mathematical literacy

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## Abstract

Mathematical literacy ability is one of the indispensable abilities in the development of mathematics education today. Currently, the mathematical literacy ability of students in Indonesia is still low. In the field of education, the era of society 5.0 has a great impact, so education must be able to produce human resources who have good mathematical literacy and are able to apply technology well with their literacy abilities. This study aims to determine how the quality of a project-based learning model with math trails assisted by augmented reality in the context of Blenduk Church is able to promote students' mathematical literacy. The research method used is design research. The data were analysed using qualitative and quantitative data analysis techniques. Qualitative data analysis techniques were used to analyse the results of student response questionnaires after conducting project-based learning with augmented reality-assisted math trails at Blenduk Church. Meanwhile, quantitative analysis techniques are used to analyse students' mathematical literacy skills obtained from student test results before and after conducting project-based learning with augmented reality-assisted math trails at Blenduk Church. However, further research is needed on the development of augmented reality-assisted learning instruments and media in other contexts to promote students' literacy skills.

**Keywords:** augmented reality; Blenduk church; mathematical literacy; math trails; society 5.0

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## Introduction

The world of education is currently faced with the problem of efforts to improve student competence. One of the competencies of students that has become a national and even international problem is literacy skills (Nisa & Arliani, 2023). Mathematical literacy ability is one of the indispensable abilities in the development of mathematics education today. This is because mathematical literacy skills are very important in helping students face challenges and solve problems in everyday life (Runtu et al., 2023). Mathematical literacy can be defined as an individual's ability to formulate, work out, and interpret mathematics in a variety of contexts, including mathematical reasoning, using concepts, procedures, and facts, in describing, explaining, and predicting phenomena. The Program for International Students Assessment (PISA) shows that Indonesian students' mathematical literacy skills are still low. Indonesia's ranking in the 2022 PISA results for mathematical literacy increased by 5 places from the 2018 PISA results, but experienced a decrease in average score to 13 points from a score of 379 to 366 (State, 2023).

The ability to literacy that is still very low is a challenge in this era of society 5.0. The era of society 5.0 is an era that requires every student and society to be able to have good mathematical literacy skills, this era seeks to better prepare human resources as an answer to the challenges posed by the industrial revolution era 4.0 which gave birth to various innovations and industrialization (Nugraha & Rahman, 2021). The current era of society 5.0 requires the application of technology in the learning process. But currently, only a small percentage of teachers or educators are able to apply the main technology augmented reality in the learning process (Santoso et al., 2023). This is a new challenge to be able to create technology-based learning media that is easy to use for both teachers and students.

Augmented reality is a technology that presents the digital world like the real world. Augmented reality is the process of expanding reality achieved through a technological process that uses digital tools such as video clips, animations, audio clips, and other digital content resulting from the integration of physical and virtual layers (Najmi et al., 2023). Augmented reality can be an interesting learning medium for students. Augmented reality-assisted learning media is one of the positive impacts of the rapid development of technology today. However, the rapid development of technology also has a negative impact, one of which is on Indonesian culture. Currently, culture in Indonesia is increasingly eroded by foreign cultures, so there is a need for knowledge related to culture to students (Fransori et al., 2023). One of the cultural knowledge to students is to include knowledge about historical buildings in Indonesia in the learning process.

Semarang City as one of the cities in Indonesia has a uniqueness that can attract the attention of many people who will visit. Semarang City has buildings, monuments or places that have their own stories. All of these are characteristics of Semarang City which has various uniqueness for the community and tourists who will visit the area (Azzahra et al., 2023). One of them is various landmarks in Semarang City. Learning mathematics by incorporating knowledge through landmarks is one interesting strategy. One of the iconic landmarks and historical buildings of Semarang City is the Blenduk Church. Blenduk Church is the oldest

church in Central Java built by the Dutch in 1753 (Karimah et al., 2019). When Indonesia became independent, the church was renamed Immanuel Church which was originally Nederlandsch Indische Kerk. The church has two floors. In 1894, W. Westmaas and H.P.A. de Wilde renovated the church by adding a second tower to the front of the building. The historic building of Blenduk Church will then be made in the form of augmented reality-assisted learning media.

The use of augmented reality (AR) can be associated with learning mathematics. Learning mathematics using augmented reality is considered beneficial for students to be more focused because they teach analytical abilities and skill (Amaliyah et al., 2023; Ebadi & Ashrafabadi, 2022). The mathematical approach is one part of the STEM approach. Currently being developed a combination of STEM and trails which is a continuation of math trails or MathCityMap (MCM), which allows the creation of mathematical paths using digital technology (Benito et al., 2023; Cahyono et al., 2023; Navianto, 2023). Furthermore, MathCityMap is a trail about mathematics that is associated with technology from smartphones and the internet, from these mathematical trails means that mathematics can be found elsewhere by doing tasks that require data collection in various places (Corlu et al., 2023).

Various learning models can be applied in the mathematics learning process that integrates augmented reality-assisted math trails, one of which is the Project-Based Learning (PjBL) model. The PjBL model is a learning approach that integrates project activities and real-world experiences in the teaching and learning process (Fajra & Novalinda, 2020; Khusna et al., 2023). This model gives students the opportunity to practice in an environment similar to the real world and develop the skills necessary to become successful professionals. Through the Project-Based Learning model on mathematics learning, students can gain a better understanding of mathematical concepts, improve problem-solving skills and interpersonal skills, and become better at collaborating (Romli & Ixfina, 2023).

The literacy skills of students in Indonesia are still very low, including students in the city of Semarang. Based on data from interviews with several mathematics teachers in class 7 of junior high school of 19 Semarang, it shows that students have less ability in solving contextual problems and questions related to geometry, algebra, probability and numbers (Wardono et al., 2018). Besides that, based on pre-research conducted by researchers to determine the initial literacy level of students in one of the junior high schools in Semarang City, the student test results obtained an average score of 27 out of 100. So there is a need for collaboration between learning models and good mathematics learning media to be able to promote students' mathematical literacy. So, the question of this study is how can the project-based learning models with augmented reality-assisted math trails in the context of Blenduk Church be able to promote students' mathematical literacy. The novelty of this research is integrating both of PjBL and AR especially for a math trail with historical components and also using a Blenduk Church as the backdrop for a math trail with AR integration could be a unique way to enhance students' mathematical literacy.

## Methods

The study used design research based on the purpose of this study (Bakker, 2018). Its purpose aligned with developing the Virtual Reality STEM Trails project (Cahyono, 2023). This design research project had three stages: preliminary design, teaching experiments, and retrospective analysis (Nurin et al., 2023). The research took place in Semarang, Indonesia, involving a local junior high school. The first stage involved introductions, the researcher conducted interviews with teachers to analyze the curriculum, student characteristics, and learning environment. The second stage was design, the researcher prepared the design of the learning media (an augmented reality-assisted math trails application) and designed learning activities. The next stage also involved developing the learning media and designing learning activities for field experiments.

Grade 8D students participated in the learning process. The researcher conducted tests to measure students' mathematical literacy skills before (pretest) and after (posttest) using the augmented reality-assisted math trails. The research instruments included the augmented reality-based learning media, student pretest and posttest questions adapted to the OECD-based PISA test framework for promoting mathematical literacy skills, and student response questionnaires. The PISA test framework focused on various aspects of mathematical literacy, including communication, problem-solving strategies, and using mathematical tools (Trisnaningtyas & Khotimah, 2022). The researchers collected data from students' pretest and posttest work for analysis to determine the effectiveness of the project-based learning model using augmented reality-assisted math trails in the context of similarity and congruence of geometric figures at Blenduk Church, as well as any increase in students' mathematical literacy skills. Mathematics education lecturers and junior high school mathematics teachers in Semarang City validated the instrument test. They confirmed that the augmented reality-based learning media, student pretest and posttest questions, and response questionnaires were valid and suitable for the research process with a score of 97.2% out of 100%.

Data analysis involved both qualitative and quantitative techniques depending on the research instruments. Qualitative techniques analyzed the student response questionnaires after the project-based learning with augmented reality-assisted math trails at Blenduk Church. Quantitative techniques analyzed students' mathematical literacy skills obtained from student test results before and after the project. The researchers used paired sample t-tests to determine if there were significant differences between the pretest and posttest results.

## Results

In the results will be presented three main components which are the steps in this design research. The three main components in this design research include design of PjBL through augmented reality-assisted math trails at Blenduk Church, teaching experiments, and retrospective analysis about student response questionnaires.

## Design of PjBL through augmented reality-assisted math trails at Blenduk church

The first stage was observation and interview with a mathematics teacher of one of the junior high schools in Semarang City regarding the curriculum, learning environment, student characteristics, infrastructure used and students' initial abilities. Based on the results of these observations and interviews, it was obtained that the curriculum used is an independent curriculum, the learning environment is very strategic and supportive to increase learning motivation because the characteristics of students have high curiosity but many do not like mathematics subjects, besides that schools are also very adequate to use augmented reality in the learning process and students are also allowed to use smartphones if necessary in the learning process.

The next stage is to design the augmented reality of the Blenduk Church building. In the augmented reality design, observations have been made at Blenduk Church to see every detail of the Blenduk Church building. Blenduk Church building can be seen in Figure 1. After observing the Blenduk Church building, then the design of the Blenduk Church building was carried out in real to virtual with augmented reality technology. Augmented reality design is done with the help of Sketchup, Blender, and Assemblr applications to get augmented reality Blenduk Church buildings in Figure 2.

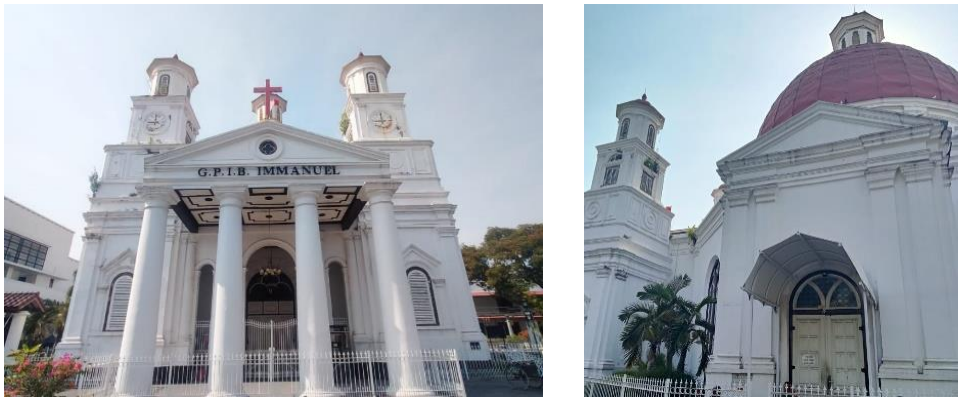



**Figure 1.** Blenduk church building

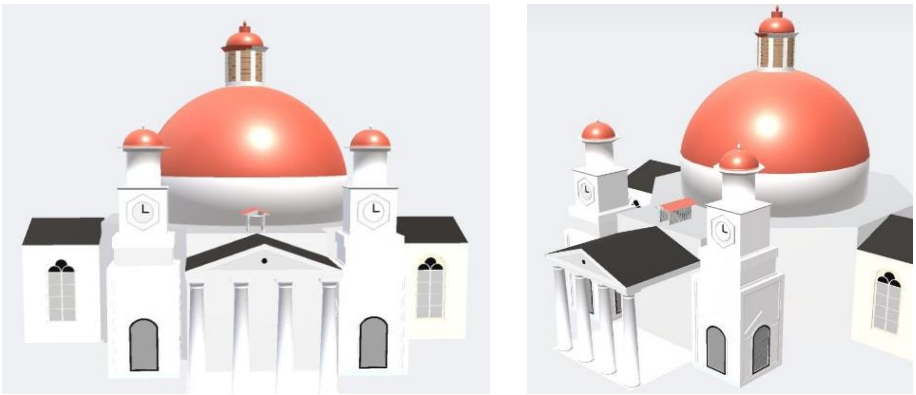


**Figure 2.** Blenduk church augmented reality design

The development of the augmented reality-assisted math trails project in this study was carried out by determining the strategy of the project-based learning model with augmented reality-assisted math trails at the Blenduk Church. This research uses a project-based learning

model because the learning model is able to support students to be more active in the learning process with a given project (Nurcahyono, 2023). Researchers use the syntax that already exists in project-based learning models with augmented reality-assisted math trails to help promote students' mathematical literacy skills. After determining the learning model strategy, an augmented reality media link is created that students can use to support the learning process. This research resulted in an augmented reality link of the Blenduk Church building that students can use in the learning process. Here's the augmented reality link that can be accessed https://asblr.com/XPfd9.

## Teaching experiments

Project-based learning model experiments with augmented reality-assisted math trails at Blenduk Church will be carried out in class 8D at one of the junior high schools in Semarang City with the following results. Before starting the learning process, students are given a pretest to determine students' initial ability to solve mathematical literacy problems related to congruence and congruence material. As a result of the pretest, students scored an average of 26.63 out of 100, with the lowest score being 21, and the highest score being 39.

The learning process is carried out with a total of 32 students and divided into 6 groups with each group consisting of five to six students. The learning process is carried out for 8 hours of meetings with each meeting always paying attention to each syntax in the project-based learning model. Before starting learning, students are introduced first to the learning media that will be used with the help of augmented reality. Furthermore, students are directed to make projects regarding awakening and congruence material in historical buildings in Semarang City. Starting from determining historical buildings, problems related to awakening and congruence, and presenting in front of the class. Student activities in the learning process can be seen in Figure 3.

At the end of the learning process, students are given a posttest to measure students' final ability to solve mathematical literacy problems related to awakening and congruence after learning with a project-based learning model with augmented reality-assisted math trails at Blenduk Church. The results of the posttest students get an average score of 78.72 out of 100, with the lowest score being 63, and the highest score being 89. The comparison results of student pretest and posttest scores can be seen in Table 1.

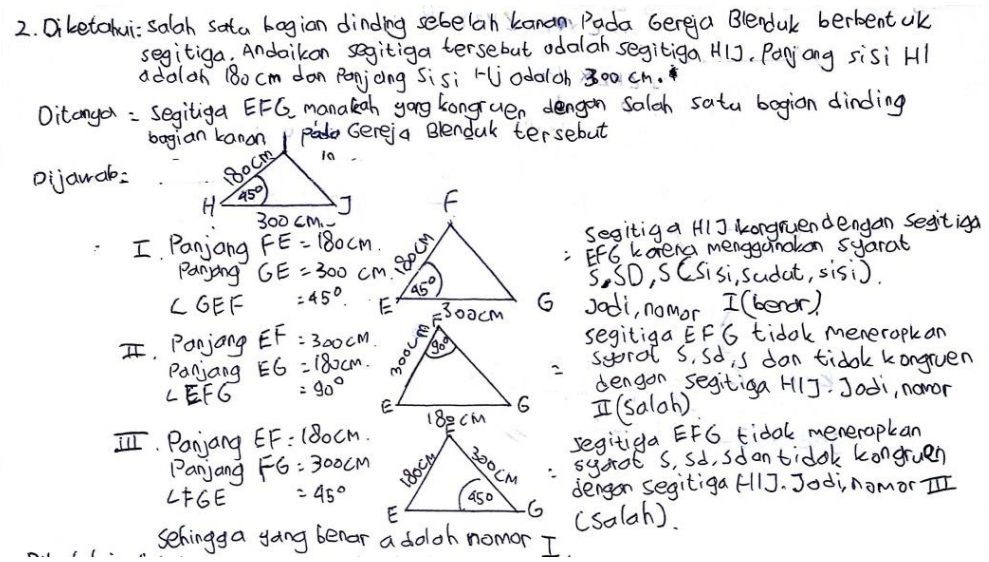
**Table 1.** Comparison results of student pretest and posttest scores

| Criterion | Pretest | Posttest |
|---|---|---|
| Minimum | 21 | 63 |
| Maximum | 39 | 89 |
| Average | 26.63 | 78.72 |

Students' pretest and posttest data results were collected for further statistical testing. The collected data is used to analyze students' mathematical literacy skills. The data of the students' pretest and posttest results were tested for normality, and it was found that the students' pretest and posttest data were normally distributed with pretest Sig values of $0.177 > 0.050$ and posttest Sig. values of $0.061 > 0.050$.

**Figure 3.** Student learning activities

In teaching experiments, students are given test questions that are able to measure students' mathematical literacy skills. The following is presented the work of one of the students in completing the congruence material test questions. It is known in this matter that one part of the right wall of the Blenduk Church is triangular, if the triangle is a HIJ triangle with the length of the HI side is 180 $cm$, the length of the HJ side is 300$cm$ and the IHJ angle is forty-five degrees ($45^0$). In this question, it is asked which of the three EFG triangles is congruent with the HIJ triangle (*show how students to devising strategies for solving problems*). Students in this case answer in detail and well starting from the question point 1 known FE length is 180$cm$, GE length is 300$cm$, and GEF angle is forty-five degrees ($45^0$), point 2 with known EF length is 300$cm$, EG length is 180$cm$, and EFG angle is ninety degrees ($90^0$), point 3 with known EF length is 180$cm$, FG length 300$cm$, as well as FGE angle forty-five degrees ($45^0$) (*communicating and representation from the statement to be mathematicising the congruence using symbolic and mathematical tools*). The results of the work explain that the EFG triangle that is congruent with the HIJ triangle is point 1 because they both apply the congruent principle of two triangles to the terms of the sides (*show the reasoning and argument*), while points 2 and 3 do not apply the congruent principle, so they cannot be declared congruent. The results of the students' work can be seen in Figure 4.




**Translation**

**It is known:** one of the walls on the right side of Blenduk Church is triangular in shape. Suppose the triangle is a HIJ triangle. The length of the HI side is $180cm$ and the length of the HJ side is $300cm$.

**Asked:** Which EFG triangle is congruent with one of the right walls of the Blenduk Church

**Answer:**

I. FE length = $180cm$

GE length = $300cm$

$\angle GEF = 45^0$

Triangle HIJ is congruent to triangle EFG because it uses the terms S, Sd, S (side, angle, side). So the EFG triangle point I is correct.

II. EF length = $300cm$

FG length = $180cm$

$\angle EFG = 90^0$

The EFG triangle does not apply the conditions S, Sd, S (side, angle, side) and is not congruent with the HIJ triangle. So the EFG triangle point II is wrong.

III. EF length = $180cm$

FG length = $300cm$

$\angle FGE = 45^0$

The EFG triangle does not apply the conditions S, Sd, S (side, angle, side) and is not congruent with the HIJ triangle. So the EFG triangle point III is wrong.

**So, the correct one is number 1**

**Figure 4.** Sample of student's work

The data from the teaching experiment was then carried out effective testing with paired sample t test can be seen in Table 2. The paired sample t test obtained that the value of mean being 52.094 with std. deviation being 8.712 and the Asymp. Sig. (2-tailed) of $0.000 < 0.050$ which means there is a difference in the average student learning outcomes for pretest and posttest which means it is effective for improving student learning outcomes after students get learning with a project-based learning model with augmented reality-assisted math trails at Blenduk Church.

**Table 2.** Paired sample t-test

| **Paired Samples Statistics** | | | | | |
|---|---|---|---|---|---|
| | | **Mean** | **N** | **Std. Deviation** | **Std. Error Mean** |
| Pair 1 | Pretest | 26.63 | 32 | 4.225 | .747 |
| | Posttest | 78.72 | 32 | 7.476 | 1.322 |

| **Paired Samples Correlations** | | | | |
|---|---|---|---|---|
| | | **N** | **Correlation** | **Sig** |
| Pair 1 | Pretest & Posttest | 32 | .034 | .853 |

| **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 | −52.094 | 8.712 | 1.540 | −55.235 | −48.953 | −33.826 | 31 | 0.000 |

## Student response questionnaires

At the end of the learning process using PjBL with augmented reality-assisted math trails at Blenduk Church, students were given questionnaires to find out student responses. Student response questionnaires are used to determine responses and measure student satisfaction after the learning process. This is in line that, one way that can be done to determine the level of student satisfaction with the learning process is through the distribution of student response questionnaires at the end of the learning process (Rahmawati et al., 2023). The following are presented the results of the student response questionnaire in terms of 5 main aspects, namely the quality of the learning media used is good, the display of interesting learning media, the

usefulness of the learning process for students, increased student learning interest, and aspects of use in the learning process are easy. The response can be seen in Figure 5.

The development carried out in this study also received a good response from students as evidenced starting from the aspect of media quality, 81% students agreed that the media used was very helpful in the learning process and made more understanding. The media referred to here is math trails assisted by augmented reality, this media has been used to help students visualize existing mathematical problems so that students can understand the problems better. The next aspect is appearance, 63% students agreed that the display on the learning media used was very interesting. Besides that when viewed from the aspect of usefulness, 82% students agree that learning media is very useful in the learning process. then in the aspect of learning interest, 89% students agree that PjBL with augmented reality-assisted math trails can increase interest to learn. The last aspect is use, 78% students agree that augmented reality learning media is very easy to use in the learning process. From the results of the student response questionnaires, it was found that PjBL with augmented reality-assisted math trails at Blenduk Church was able to help the students' learning process and also can increase motivation and reduce student boredom in learning mathematics. When students are helped, it is hoped that the increase in students' mathematical literacy can be achieved well.

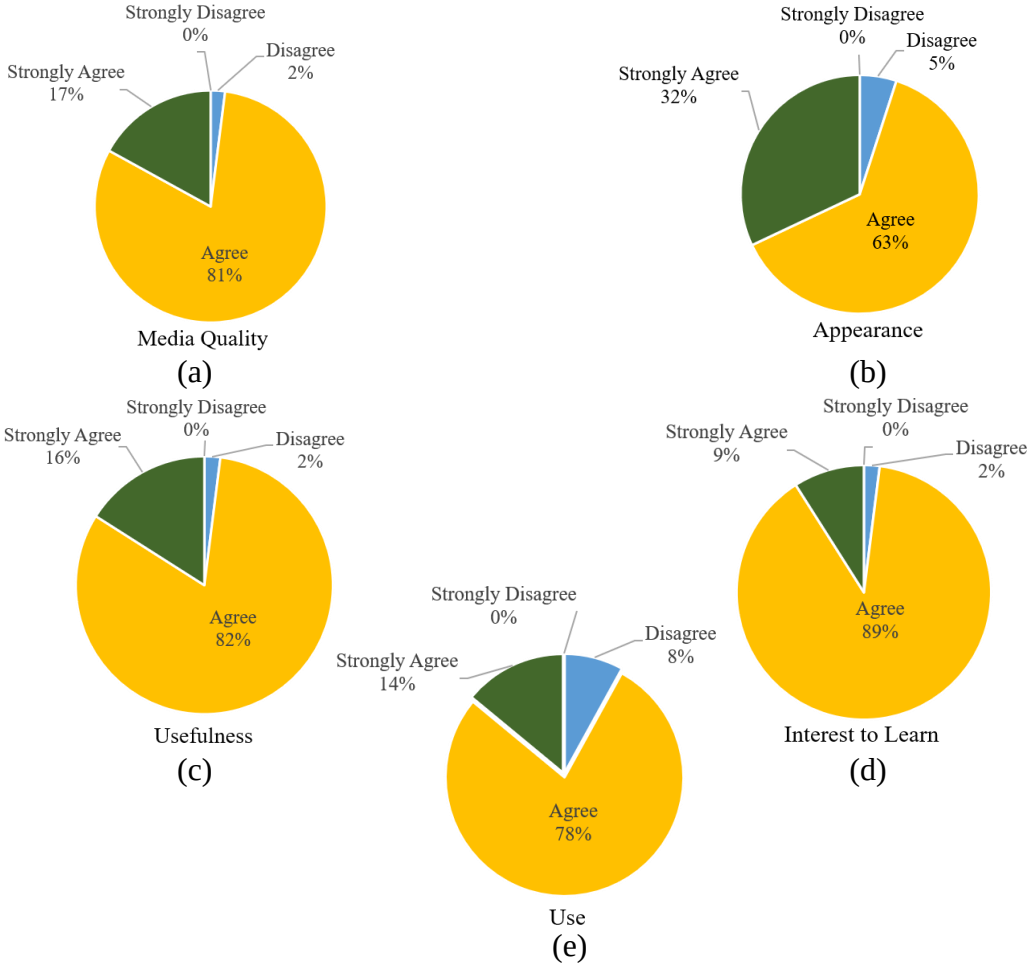



**Figure 5.** Student Response Questionnaires of PjBL with augmented reality-assisted math trails at Blenduk Church from aspect (a) Media Quality; (b) Appearance; (c) Usefulness; (d) Interest to Learn; (e) Use

## Discussion

The project-based learning model with augmented reality-assisted math trails at Blenduk Church was able to promote students' mathematical literacy skills. This is in line with the significance result of 0.000 which means that there is a significant difference between students' pretest and posttest results. The selection of PjBL as a learning model is able to help in the process of learning good mathematics for students. This is in line with the fact that through practical, real-world problem-solving exercises, PjBL may aid students in gaining a better comprehension of mathematical ideas and abilities (Dorimana et al., 2022). In an educational context, the use of technology-assisted learning media can promote students' mathematical literacy skills by introducing students to something more interesting (Dewi & Maulida, 2023). Students can feel a deeper connection between math and the historical buildings around them, motivating them to learn math better. The outcome from the paired sample test shows an average result deviation between both tests learning, so there is an impact from using the PjBL strategy in learning mathematics assisted by augmented reality (Cahyono et al., 2020; Fatahillah & Faradillah, 2023).

Students' mathematical literacy skills can also be seen from the results of students' work on story question exercises that have been adjusted to test indicators from PISA. Practice questions that have been adjusted to test indicators to measure students' mathematical literacy skills from PISA are able to measure the mathematical literacy ability of each student (Fatra et al., 2023; Ozkan & Ozaslan, 2018; Suryadi & Umbara, 2019). The results of the student's work have included all test indicators of the student's mathematical literacy ability. Starting from making a good mathematical model of the story problem given, and providing answers with good arguments and using the concepts of awakening and congruence in triangles well. In the context of augmented reality-assisted math trails, the use of technology can help improve accessibility, effectiveness, and efficiency in learning, which in turn can promote students' literacy skills . In a study conducted on the influence of technology use in education, it was found that the use of technology can help increase students' active participation and learning motivation and help improve learning achievement (Cao & Yu, 2023; Unal & Cakir, 2021). In augmented reality learning media at Blenduk Church, students can see the real Blenduk Church from various sides that can help students identify the awakening and congruence that exists in the building.

The development of augmented reality-assisted math trails at Blenduk Church also gives students access to more varied and structured learning media, so that it can help them understand the concepts of awakening and congruence in mathematics better, and can help students to be more active in learning. Students' mathematical literacy ability can also be seen from existing indicators ranging from students being able to formulate real problems in determining congruence and congruence, using mathematics in solving these problems, and interpreting solutions in given problems, and being able to evaluate solutions in problems of awakening and congruence in problems. Thus, students have met the existing indicators on mathematical literacy ability. This is in line with idea that the use of augmented reality in

learning can stimulate problem-solving abilities, especially in students' mathematical literacy abilities (Guntur & Setyaningrum, 2021; Pujiastuti & Haryadi, 2023; Sarkar et al., 2020).

The development carried out in this study also received a good response from students. From these results, it is proven that students' responses after getting PjBL learning with augmented reality-assisted math trails at Blenduk Church can have a good impact and be able to help students in learning mathematics, especially effective in improving students' mathematical literacy skills. This is in line with the fact that a good response from students provides an easier understanding of the material taught and students do not feel bored in the learning process which results in an increase in student scores in classroom learning (Mardana et al., 2023). So, the development of PjBL with augmented reality-assisted math trails at Blenduk Church can be developed in the learning process for students.

## Conclusion

Through this research, it was found that the project-based learning models with augmented reality-assisted math trails in the context of Blenduk Church was able to promote students' mathematical literacy skills. Mathematics learning using a project-based learning model with augmented reality-assisted math trails is able to promote students' mathematical literacy skills as seen from the significant difference in students' pretest and posttest results before and after getting the learning. This is also supported by student responses that the development carried out are able to increase students' interest in learning and reduce student boredom in learning mathematics.

The researcher also suggests for teachers to integrate augmented reality and project-based learning in their classrooms to help the learning mathematics process for students. However, there is a need for continuous development of other mathematical materials and further trials to measure the mathematical literacy ability of students with a larger population from this study to be more accurate in measuring the level of effectiveness.

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### Conflicts of Interest

In relation to the publication of this manuscript, the authors declare that there is no conflict of interest. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies, have been completed by the authors.

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## Author Contributions

**Muhammad Andi Nugroho:** Conceptualization, writing - original draft, methodology, formal analysis, investigation, data curation, visualization; **Indriana Yulandari:** Resources, Writing - review & editing, project administration; **Adi Nur Cahyono:** Validation and supervision.

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