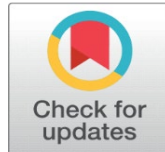# DEVELOPMENT OF AUGMENTED REALITY BASED GEOMETRY LEARNING MEDIA ORIENTED TO BALINESE ARCHITECTURE TO IMPROVE ABILITY STUDENT MATHEMATICS SPATIAL

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ABSTRACT

Media Augmented Reality is very relevant for student learning based on information and communication technology. However, learning using AR has not been widely used, especially when learning mathematics. This study aims to determine the quality of augmented reality media oriented towards Balinese architecture and the implementation characteristics when using the media in learning. AR media packaged in an android mobile application is included with a marker to scan 3D objects to improve students' mathematical spatial abilities in geometry learning. This research is design research using the Plomp model. The research subjects were students of class X SMA. So, the data collection methods of this research are observation, interviews, tests, and questionnaires. The validity test results show that the media is very valid, scoring 3.68. The practicality test showed that the development included AR media in the efficient category with a score of 3.5. Finally, the effectiveness test indicates that the AR media developed effectively increases spatial ability with an average score of 85, reaching the completeness criteria. This result shows that AR media is oriented to Balinese architecture with valid, practical, and effective quality. One of the characteristics of the media developed is that AR media can display 3D objects so that students are given space to explore, imagine and conclude the material obtained. Then, the characteristics of using the media, namely AR media, can be used as an alternative to spatial geometry media in overcoming the limitations of presenting material in schools.

Keywords: AR Media, Geometry, Balinese Architecture, Students' Mathematical Spatial Ability

1. INTRODUCTION

Along with the times, Indonesia has now entered the era of the Industrial Revolution 4.0, which has introduced efficient and flexible mass production technology. In this case, of course, what has emerged are sophisticated digital machines and platforms which operate independently or in coordination with humans. In addition, this revolution has brought information and technology that has influenced learning in schools. Everyone will be able to access all the information and materials quickly. Especially in education, teachers and students

must be ready to develop high creativity in the era of the industrial revolution 4.0. If we can't develop along with the revolution, then in the next 30 years, we will experience great difficulties.

Since March 2020, to slow down the spread of the Coronavirus in the community, the Ministry of Education and Culture (Kemdikbud) has responded with a policy of learning from home, through distance learning, or online. But, because of the Covid 19 pandemic, it isn't effortless to determine whether the student knows and understands the material or not because all the learning process is done at home. Teachers also have difficulty monitoring students as a whole. Based on the results of observations and a UNICEF survey from 18-29 May 2020 and 5-8 June 2020 stated in the form of a percentage that there are 66% of 30 million students from various levels of education in 34 provinces in Indonesia admitted that they are not comfortable studying at home during the pandemic. That statement is because they even lost interest in learning.

Based on the results of interviews conducted with one of the mathematics teachers of SMA Negeri 1 Kuta Badung, in learning mathematics, there are many obstacles faced, especially in class 12 semester 1, especially the delivery of spatial geometry (three dimensions) in online learning. Students are reluctant to explore the work and find out the actual concept of the material. The teacher provides material and examples of questions as usual. However, when given new inquiries related to spatial geometry, students are still confused about which formula or concept to use. Students have not been able to imagine and think about problem-solving solutions from the existence of the geometry of space (three dimensions).

Jawa Pos' article revealed another cause of students' difficulties in learning three-dimensional geometry in March 2020. The report states that students have a three-dimensional stigma which is one of the materials that is quite difficult to reach because, in addition to only understanding the concept, students must be able to visualize the shapes of the problem in three dimensions. Another statement research on learning this material is that many students still misunderstand the concept or cannot mobilize their thoughts to solve three-dimensional problems. Therefore, teachers must also find the right strategy in learning mathematics, especially three-dimensional material, so students can easily understand the material.

In addition, the interview also obtained results. For example, when students were given spatial geometry questions (three dimensions) based on aspects of mathematical spatial abilities, many students were still confused and even had difficulty solving the problem. Students are also not used to imagining the geometry of space. Moreover, learning is done online, so students have not entirely accepted the concept, so the main problem found is the lack of mathematical spatial ability.

Spatial ability in students means that every student is required to develop spatial abilities and senses, which are very useful in understanding relations and properties in geometry to solve mathematical problems, it was stated to the National Academy of Science. Issues in the field related to geometry problems are caused by the high level of abstraction of geometric objects and the lack of visualization of imagined things.

Researchers also made observations by giving pretests to students to determine the extent of students' spatial abilities in learning space geometry. The results of student observations showed that of the four questions given, 2 of the answers were still inaccurate. As many as 30 people took the test, and only 30% of students answered correctly, while 70% were still wrong in answering the

questions. Students have not met the elements of spatial orientation and spatial perception on mathematical spatial abilities. Spatial orientation is a student's ability, which refers to identifying the position or direction of objects in space. Meanwhile, spatial perception is the ability to analyse and feel objects' size, shape, movement, and orientation. In the final answer, students find it difficult to imagine the space and distance on each line segment. Therefore, there is a need for learning media to facilitate students in learning activities at home for mathematical spatial abilities.

In addition to interviews with teachers and giving preliminary tests, interviews were also conducted with students who got the results that students were less interested in learning and only focused on the module. Therefore, it is hoped that spatial geometry learning will be more exploratory and exciting, better presented directly by some illustrations of natural objects.

To support the learning process described above, we need a learning media that is appropriate to the material and contains things related to the material to be delivered; even the media can be close to students' lives. The learning media in question is augmented reality media which contains various concrete objects close to students that invite students to explore their spatial geometry knowledge through activities designed to be able to demand students in each of their learning activities, including in determining the position of space, imagining the spatial framework and the process of completing problems with the geometry of space. Augmented reality (AR) media is an option for advancing educational technology. It can show digital objects such as images, videos, and text, then place natural things in the environment scanned by the camera by the user, and AR will focus on enriching it with virtual information.

In line with Liu et al. (2019) statement on mathematics education, they report that AR positively affects student learning and attitudes in responding to mathematical problems, especially in geometry material. Then also, an idea from Saidin et al. (2015) makes it clear that the advantages of AR in education show significant potential to be integrated into the teaching and learning process on materials that require students to visualize.

AR learning media will be more interesting if it is developed with an orientation to the surrounding environment. In this case, space geometry material related to Balinese buildings (Balinese architecture) will be presented. Later, AR media has the privilege of displaying objects adapted to the actual situation of the shape of the building and then being accommodated for learning geometry in mathematics. Finally, students can imagine some mathematical concepts using a scan marker.

The reason for choosing to develop AR media oriented to Balinese architecture is motivated by previous studies. Based on research conducted by Pangestu et al. (2019) and Raudhatul (2020) obtained the same result that AR-based learning media is said to be effective in helping students increase their interest in learning. Therefore, AR-based media can facilitate teachers in attracting students' interest in education. Other research, such as that conducted by Setiowati (2018), stated that AR could improve student learning outcomes in mathematics subjects with flat-sided geometry. However, unlike Mustaqim and Kurniawan (2017), AR has several drawbacks; namely, it is sensitive to changes in viewpoints and not too many makers, even though AR has also been proven to replace learning modules that do not yet exist in schools in virtual or media form to make learning easier. In addition, the research results from Cristian Young (2015) showed that AR media designed on the mobile platform could not fully describe the object's environment as a whole, so further research needs to be done to create object markers.

This research also conducted that research to develop AR media, especially building illustrations. Other findings that encourage this research are Hasanah. (2019) using the main building of the Banyuwangi English dormitory as a learning medium. The results of this study indicate that the architecture of the main building of the English Dormitory has forms that are considered representations of the geometric concept, namely flat shapes, flat side spaces, similarity and congruence, symmetry, and geometric transformations. In this research, it's just that it has not been developed in the form of AR. In addition, other research is in the form of analysis of geometry problem-solving abilities through an AR-assisted project-based learning model conducted by Muwahaddah (2020). The results showed that learning with the AR-assisted model was adequate, but the research was limited to junior high school materials, building flat-sided buildings, and historical relics.

Based on the literature study from several studies, literature found different results studies regarding the use of media with AR, such as AR media, were developed only as illustrations of spatial shapes and forms. Therefore, further research is needed to explain specifically that AR-based learning media can improve students' aspects of interest and spatial ability in learning mathematics. In this study, we will discuss the development of AR media in Balinese architecture-oriented mathematics learning, which is currently unavailable. This research is a mission as an effort to increase students' interest in learning mathematics, and students' spatial abilities, strengthening the concept of three-dimensional space geometry and realizing meaningful mathematics learning. The problems raised are: How to produce learning media for spatial geometry based on augmented reality-oriented Balinese architecture with characteristics to improve students' mathematical spatial abilities. And how the aspects of learning implementation using augmented reality improve students' spatial mathematical abilities.

2. MATERIALS AND METHODS

Based on the research objectives or problems to be solved, the type of research used is Design Research. Researchers expect the quality of the resulting product, namely a valid, practical, and effective product, then know the characteristics of the use of the media. In this design research, the research subjects are experts, 10th-grade high school students, and teachers.

This type of research is design research with a development study type Plomp. The object of this development research is an AR media constructed by a mobile application, oriented to Balinese architecture ethnomathematics, and connected to the Instagram platform. The media was processed with Blender, SketchUp, Unity, and Vuforia software. The main instrument in this study is the content validity instrument and instrument which measures construct validity. Then there are also instruments to measure the practicality of AR media using observation sheets on the implementation of media use, teacher response questionnaires, student questionnaires, and question sheets (testing the effectiveness of the media). Then the data to be searched are validity test data, practicality test data, and effectiveness test data.

In terms of detail, each stage of design research. According to Plomp, the implementation of design research of the type of development study includes 3 phases, namely: (1) Preliminary research, (2) prototyping, and (3) assessment. Details are in the following image:

Figure 1
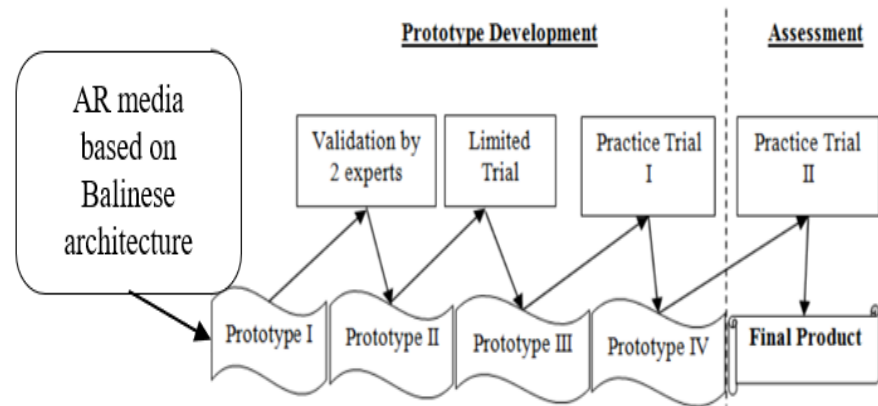
Figure 1 Prototype Development

In design research, the data collection methods are observation and interview, ways of giving questionnaires/questionnaires to students and teachers, and test methods. Aspects of assessment used are media display, media content, student interest, interest in media, adversity quotient, self-efficacy, and student motivation. In this case, the teacher tests the media's effectiveness in improving students' mathematical spatial abilities.

Data analysis techniques used in qualitative research include interviews, data reduction, analysis, data interpretation, and triangulation. From the results of the data analysis, the result can then conclude. In addition, after analyzing the data, it is used as material for revising AR learning media. Then the effects of student work and their interactions will also be recorded as evidence in this study.

3. RESULTS AND DISCUSSIONS
3.1. RESULTS

The initial research stage is carried out by carrying out problem identification to obtain data about problems and solutions that research will use to improve the quality of mathematics learning in the classroom. This analysis was carried out in class X mathematics learning at SMA Negeri 1 Kuta through observation activities, studying learning media for students, and conducting interviews with related teachers and students.

Preliminary research begins by reviewing some of the literature from previous years. Based on the studies, no one has made AR media oriented to Balinese architecture. The AR media that is designed only illustrates flat and curved side spaces such as images of blocks, cubes, tubes, etc. Then, based on preliminary research done at SMA Negeri 1 Kuta, the needs analysis stage is carried out by collecting information to find problems in the mathematics learning process. Information collection is done by observing the teacher teaching and paying attention to each student's activity. Based on the observations, the situation shows that the learning process has not entirely run optimally. The teacher still seems to dominate, while students sometimes struggle to express what they have not understood during the learning process. Research also made observations to see the infrastructure and learning environment in the classroom. The infrastructure at the school is adequate. There are three computer classrooms and a one-touch monitor for hybrid learning, and during school, students can borrow gadgets such as tablets.

Then regarding the learning atmosphere, during the learning process, it is always conducive; students occasionally speak only if the teacher asks to answer or ask questions.

Based on interviews with several mathematics teachers, teachers have never used AR as a medium in learning mathematics. Teachers rely more on printed books to convey material to students. Teachers sometimes use learning videos or GeoGebra illustrations in learning geometry. The interview also found that the abilities of students varied. The next stage is to find out students' ability; apart from interviews with students, an online questionnaire is also distributed. The teacher stated that students' academic ability was still low, evident from the daily tests' results. Only 17 of 36 students met the KKM threshold. Students also stated that many mathematics materials were not fun, not practical, and less innovative. The videos the teacher gave are too long, and most of the questions are difficult to do.

Furthermore, the researcher reviewed the 2013 curriculum for the mathematics subjects of class X SMA at the curriculum analysis stage. Analysing the curriculum aims to determine whether the material being taught follows the expected competencies. Curriculum analysis is focused on the analysis of KI and KD. The results of the study of KI and KD contained in the content standard were translated into indicators of mathematics learning. Based on this analysis, the curriculum concluded that the material used in developing learning media was space geometry material (three dimensions) for class X science. Then, a concept analysis was also carried out to determine the content and subject matter needed in the development of AR media. The central concept is all the material presented in the subject matter of space geometry.

In addition to the above, the results of further interviews found that students, when faced with the process of solving problems related to building space, are sometimes not interested in participating in learning because students find it difficult to imagine the shape and position of the wake Building space in spatial geometry material is always depicted on the board with two-dimensional shapes, so students need to better understand and imagine accurate figures independently. Moreover, when students are faced with new questions from the teacher which are different from the questions exemplified by the previous teacher. Students find it difficult and are more likely to memorize existing formulas without understanding where they came from. As a result, when working on the practice questions, if the questions or problems given are slightly different from the examples, students will experience confusion in solving the issues presented, so teachers often cannot apply student-centered (student-centered learning).

When studying space geometry material, the media and teaching materials provided are not close to the students. The problems presented in the teaching materials and the media are still too general and not always around students. In addition, the teacher has difficulty illustrating a three-dimensional space which causes students to feel less able to understand the material clearly.

In addition to the problems above, research obtained several documents to recapitulate the final grades for the odd semester grade X students in the 2021/2022 academic year at SMA Negeri 1 Kuta. Data on the results of the bizarre semester end of the semester for classes X IPA 1, X IPA 5, and X IPA 6, respectively, can be seen in the appendix. Although the results of the recap show that the results obtained by students are still not optimal, the learning outcomes that are not optimal can be seen from the number of students who get scores below the learning completeness standard set by the school.

The findings obtained from observations, interviews, and data collection indicate that the implementation of learning for mathematics subjects is still not implemented optimally. Less optimal learning requires a new revolution to overcome existing problems. The alternative solution to overcome the issues being faced is to design learning that can invite students to construct their knowledge, explore and provide understanding to students that mathematics does not tend to memorize formulas or other definitions. Still, students can understand the meaning behind the given procedures and descriptions of math terms. As a result, students will feel that learning mathematics becomes more meaningful.

As in spatial geometry learning, teachers need to strive for a meaningful learning atmosphere by inviting students to learn to see and use objects around them as objects to construct their knowledge. Students will also develop their mathematical spatial abilities. This statement is in line with Sugiarni et al. (2018) statement that learning geometry improves students' spatial ability by imagining, comparing, guessing, determining, constructing, presenting, and finding information from visual stimuli in space. Teachers must also design learning activities according to essential competencies that are problem-based and related to the surrounding environment. Activities carried out by students make learning more meaningful, which will affect students' memory considering the learning that occurs in students' daily lives.

The teaching media that will be developed in this research is augmented reality-based spatial geometry learning media oriented to Bali's architecture concept. The learning media referred to in this study are in the form of an android mobile application plus several markers that students will scan while using the media. Furthermore, this AR media presents illustrations of Balinese architecture in mathematics learning, thus giving a new nuance that learning mathematics is not only confined to the classroom but can also visit or interact with local culture Richardo (2016).

At the development stage, the researchers designed the product that was developed in the form of augmented reality-based spatial geometry learning media oriented to architecture in Bali. The designs produced at this stage are: (1) The media in the form of draft images and mock-ups of Balinese buildings (bale meten and bale dangin) are used as learning objects for spatial geometry (three dimensions). Then analyse the material on KD is related to the geometry of space (three dimensions). The next step is to sort out and adjust the shape of the room and images from Balinese architecture, which will be inserted in the display of the media material that will be discussed to match the material. The problems given in AR learning media are adapted to contextual issues that exist around students. Students are invited to explore AR media by looking at the relevance of the material with the existing 3D illustration presentations. Students begin to understand the definition of each spatial geometry material and can solve the problems given to the media. (2) The lesson plan adapted to the curriculum applied to the school where the research is conducted uses the 2013 curriculum and the Merdeka curriculum experiment.

The following authors also attach a video of using the application in class: https://drive.google.com/file/d/1XxgHXoC2_quE0YbRp_5m8FWa8y2SYMti/view?usp=sharing

Figure 2
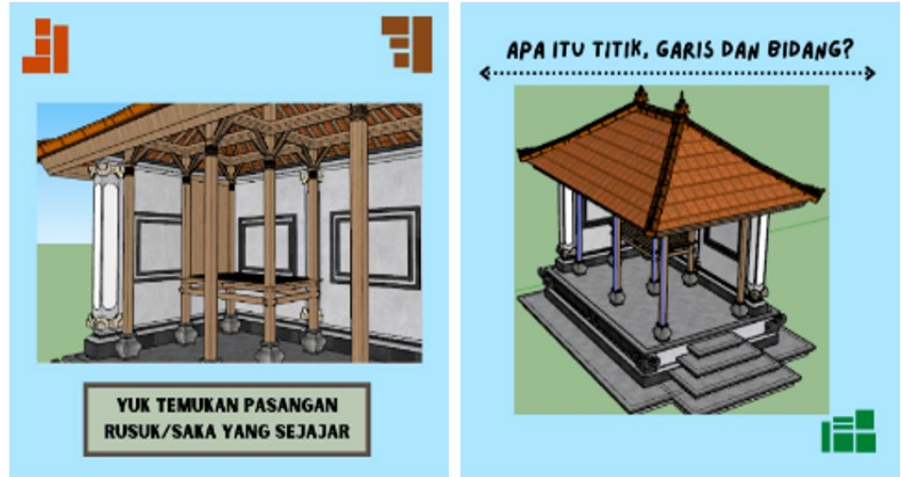
Figure 2 illustration of AR marker

Figure 3
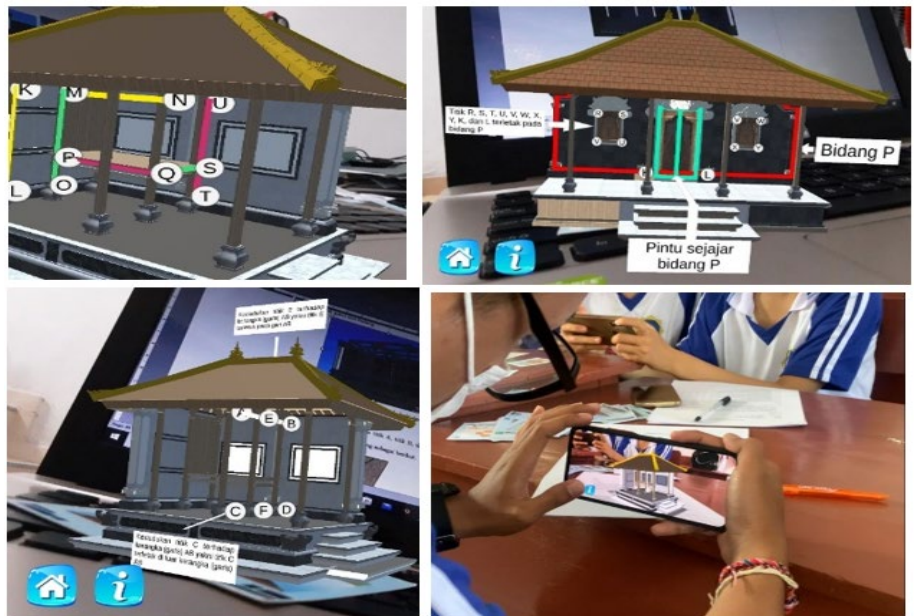
Figure 3 illustration of scan AR

The designed AR learning media was then analysed according to the design research stages. The results of the analysis by validators on AR and Lesson Plan of media are summarized as follows:

Table 1

Table 1 Summary of AR and Lesson Plan Media Assessment Results form Validators					
No.	Object	Average of Validator I Score	Average of Validator II Score	Average	Category
1.	Media AR Math Mansion	3,76	3,60	3,68	Very Valid

2.	Lesson Plan	4	3,52	3,76	Very Valid

Refer to the table data. It can be concluded that the validity value of AR Math Mansion media oriented to Balinese architecture for high school students developed in this study is included in very valid criteria with an average validity score of 3.68. At the same time, the average RPP score is 3.76, which is also included in the very valid criteria.

Table 2

Table 2 Summary of Analysis Results of AR-based Learning Media Implementation Sheet on Limited Trial (X IPA 5)				
Average of Score (Sr)		**Total**	**Sr Total**	**Explanation**
Observer 1	**Observer 2**			
3	2,87	5,87	2,93	Practical
3,12	3,12	6,24	3,12	Practical
Overall Score Average				3,02 (Practical)

Based on the table above, it is found that the overall average score in the limited trial is 3.02, which is included in the practical category. Therefore, the results of the implementation sheet in this little trial were one of the reasons for deciding that this AR media could be tested at the next stage, namely in the field trial I, because it was included in the practical category. The following are the results of the AR media implementation sheet analysis in the field trial I in class X IPA 1, as shown in Table 3 below.

Table 3

Table 3 Summary of Analysis Results of AR-based Learning Media Implementation Sheet on Field Trial I (X IPA 1)				
Average of Score (Sr)		**Total**	**Sr Total**	**Explanation**
Observer 1	**Observer 2**			
3,25	3,12	6,37	3,18	Practical
3,37	3,25	6,62	3,31	Practical
3,37	3,37	6,74	3,37	Practical
Overall Score Average				3,28 (Practical)

Based on the table above, the average score of the two observers and the categories in each meeting on implementing the developed learning media is obtained. The summary shows that implementing learning media is in the practical category. If viewed as a whole, the average score in the field trial was 3.18. Therefore, based on the rules of practicality criteria used in the study, it was concluded that the developed media belonged to the practical category. The relevant category obtained by the researcher in the field trial I was one of the reasons for deciding that AR media met one of the functional requirements of the media (other requirements can be seen from the results of student response questionnaires and teacher response questionnaires) so that it can be tested at a later stage namely the field trial II. The following is the result of the analysis of the AR media implementation sheet in the second field trial in class X IPA 6, as shown in Table 4 below.

Table 4

Table 4 Summary of Analysis Results of AR-based Learning Media Implementation Sheet on Field Trial II (X IPA 6)				
Average of Score (Sr)		**Total**	**Sr Total**	**Explanation**
Observer 1	**Observer 2**			

3,37	3,25	6,62	3,31	Practical
3,5	3,5	7	3,5	Very Practical
3,75	3,62	7,37	3,68	Very Practical
Overall Score Average				3,5 (Very Practical)

Based on Table 4 above, the average score of the two observers and their categories in each meeting was obtained on implementing the developed AR learning media. The summary shows that the implementation of AR media in each session has various scores and is in very practical criteria.

In addition, a summary of the results of the analysis, which is the result of the questionnaire responses of students and teachers during learning using AR media developed in limited trials, field trials I and field trials II, respectively, are as follows.

Table 5

No.	Trial	Average of Score	Category
1.	Limited	3,14	Practical
2.	Field Trial II	3,19	Practical
3.	Field Trial II	3,25	Practical

Table 5 Summary of Results of Student Response Questionnaire Data Analysis

Table 6

No.	Trial	Average of Score	Category
1.	Limited	3,41	Practical
2.	Field Trial II	3,67	Very Practical
3.	Field Trial II	3,83	Very Practical

Table 6 Summary of Teacher Response Questionnaire Data Analysis Results

Finally, at the development stage, according to Plomp, the assessment of students' mathematical spatial abilities was carried out by giving a test at the end of each meeting in field trials one and field practices 2 to see the increase in product effectiveness in the form of AR media which consisted of 4 description questions. The grid for the students' mathematical spatial ability test, the students' spatial ability test questions, and the scoring rubric used in this study are shown in the appendix. The summary of students' mathematical spatial ability test results based on field trials one and field trials two can be seen in the following table.

Table 7

No.	Trial	Average of Score	Criteria
1.	Field Trial II	80	Complete
2.	Field Trial II	85	Complete

Table 7 Summary of Students' Mathematical Spatial Ability Test Results

Interviews and observations were again carried out at the end of the study to obtain maximum information. In addition, interviews were conducted with students and teachers in schools. The results of interviews obtained by researchers from teachers after the research took place were that the teachers felt happy to be facilitated by interactive new media. The teacher thought the students were more active than usual because they were given media that had never been used. The teacher also feels that the designed AR learning media makes it easier for students to learn spatial geometry, especially in exploring the shape of three-dimensional space. In the interview, the teacher suggested that more detailed instructions for

using the product be made, and it is better to make it in the form of an AR mini-book. Then regarding the tests carried out by students, students' answers and completions look varied but to the concept of three-dimensional space geometry.

In addition, the results of interviews with several students who have used AR media during spatial geometry learning are that students feel enthusiastic, and their curiosity about AR is very high. Students with their respective groups explore in turn. There are also inputs from students on the media and the implementation of learning, including 1) students suggesting that AR media can also be used on gadgets with the IOS system. 2) instructions for use to be more detailed, and 3) AR media can also be integrated into other materials. The weakness of AR media found by students is that when the media is used for a long time, the student's cell phone heats up quickly, and the battery is entirely drained. But so far, these obstacles have been overcome because AR media has been repackaged into a simpler application size. Students also said AR media is efficient because it does not require a quota or internet network access.

The results of observations from researchers found that AR media's learning atmosphere was more active while using AR media. Students ask many questions and statements about the material in the media. Students help each other when trying to explore AR media. Media use was maximized during the two weeks of the study. Then related to the final test, some students wrote answers in detail. Students write it down from what is known and what is asked. Then students concluded the results of their solutions. This result indicates that students have been said to be able to meet the indicators of student's spatial abilities. Students answer correctly and according to the concept. Thus, based on the previous explanation, AR learning media oriented to Balinese architecture meets the criteria of effectiveness as a developed learning medium. Therefore, overall, this research was successful in developing valid, practical, and effective AR media to improve the mathematical spatial ability of high school students.

3.2. DISCUSSIONS

Research on the development of spatial-based mathematics learning media shows increased students' mathematical spatial abilities in spatial geometry material. This increase is indicated by the rise in the value before and after using AR Math Mansion media in learning activities. The utilization of technology can be used as a means of supporting learning activities for students Hanum (2013). AR media is packed with Balinese architectural illustrations, and this is in line with which states that cultural-related ideas should be integrated into mathematics learning to help students see creativity and beauty in mathematics. The development of Balinese architecture-oriented AR media resulted in the final product in the form of an android application discussing space geometry material. Augmented Reality in media development provides more precise information by presenting particular objects virtually to add data and a good understanding of the information. This information is reinforced by previous researchers who stated that Augmented Reality increased students' motivation and higher-order thinking skills Buchori et al. (2017). Learning resource products in AR applications are converted into .apk formats with a size of 143 MB.

The learning media developed in this research is the Math Mansion mobile application. Submission of material in the generated AR media can be made offline, with materials, evaluation sheets, and illustrations of spatial structures with augmented Reality. The AR media developed has two critical components: the main and supporting elements. The main features in AR media include materials, AR

illustrations, and student evaluations. The main aspect of AR media development aims to improve students' mathematical spatial abilities. Supporting components in the development of AR media include: 1. The initial appearance, 2. Cover, 3. Instructions for using the application icon/guide, 4. Identity and references from the media. The supporting component in the development of AR media serves as an adjustment of the design development to the material and needs of students to attract students' attention to the material geometry of space (three dimensions) in learning activities.

Based on the findings described in the research results, empirical evidence is obtained that the development of android-based AR in spatial geometry learning is characterized by and can improve students' mathematical spatial abilities. This study follows the design research procedure (Plomp), which begins with the preliminary research, prototyping, and assessment phases. Starting from preliminary investigation, in this phase, activities are carried out in the form of the preliminary analysis in the form of identifying a learning problem to obtain data regarding field needs to improve the quality of mathematics learning in the classroom. In the preliminary research phase, researchers began to develop learning media in the form of an AR mobile application-oriented to Balinese architecture. Furthermore, AR media is seen for its feasibility or quality as a learning medium to obtain the final prototype in the prototyping phase. Some inputs range from the appearance of the media, the material's editorial, and other AR media improvements. The final phase is the assessment phase; at this stage, a field test is carried out using prototype IV by mobilizing students in a different class than before, namely students in class X IPA 5, which consists of 36 people. In addition, observations (observations) and the provision of response questionnaires were carried out to see the implementation and practicality of the AR learning media. The results of the second field trial found that the AR media had been declared to meet the criteria of usefulness and effectiveness. So, all forms of improvement were used as revision material, and the final product was obtained in the finalization.

Regarding the quality of learning media, the average score for the validity of AR-based learning media based on Balinese architecture is 3.68. The score is in very valid criteria so that the developed AR media meets the validity criteria. AR media can also be said to be practical because it can be seen from the recap of the learning implementation sheet. The results show a score of 3.02 in the limited trial, 3.28 in the field trial I, and 3.5 in the field test II, and the last trial is categorized as very practical. The average score of student responses to the implementation of AR media in the limited trial, field trial I, and field test II were 3.14, 3.19, and 3.25, respectively. The three scores are included in the practical category. The average teacher response score on the implementation sheet of AR media implementation in the limited trial was 3.41 and included practical criteria.

Research on the development of spatial-based mathematics learning media shows increased students' mathematical spatial abilities in spatial geometry material. This increase is indicated by the rise in the value before and after using AR Math Mansion media in learning activities. The utilization of technology can be used as a means of supporting learning activities for students Hanum (2013). AR media is packed with Balinese architectural illustrations, which is in line with Boaler's research (2016) which states that cultural-related ideas should be integrated into mathematics learning to help students see creativity and beauty in mathematics. The development of Balinese architecture-oriented AR media resulted in the final product in the form of an android application discussing space geometry material. Augmented Reality in media development provides more precise information by

presenting particular objects virtually to add data and a good understanding of the information. This information is reinforced by previous researchers who stated that Augmented Reality increased students' motivation and higher-order thinking skills Buchori et al. (2017). Learning resource products in AR applications are converted into .apk formats with a size of 143 MB.

The learning media developed in this research is the Math Mansion mobile application. Submission of material in the generated AR media can be made offline, with materials, evaluation sheets, and illustrations of spatial structures with augmented Reality. The AR media developed has two critical components: the main and supporting elements. The main features of AR media include materials, AR illustrations, and student evaluations. The central aspect of AR media development aims to improve students' mathematical spatial abilities. Supporting components in the development of AR media include:

- The initial appearance.
- Cover.
- Instructions for using the application icon/guide.
- Identity and references from the media.

The supporting component in the development of AR media serves as an adjustment of the design development to the material and needs of students to attract students' attention to the material geometry of space (three dimensions) in learning activities.

Based on the findings described in the research results, empirical evidence is obtained that the development of android-based AR in spatial geometry learning is characterized by and can improve students' mathematical spatial abilities. This study follows the design research procedure (Plomp), which begins with the preliminary research, prototyping, and assessment phases. Starting from the preliminary investigation, in this phase, activities are carried out in the form of the preliminary analysis in the form of identifying a learning problem to obtain data regarding field needs to improve the quality of mathematics learning in the classroom. In the preliminary research phase, researchers began to develop learning media in the form of an AR mobile application-oriented to Balinese architecture. Furthermore, AR media is seen for its feasibility or quality as a learning medium to obtain the final prototype in the prototyping phase. Some inputs range from the appearance of the media, the material's editorial, and other AR media improvements. The final phase is the assessment phase; at this stage, a field test is carried out using prototype IV by mobilizing students in a different class than before, namely students in class X IPA 5, which consists of 36 people. In addition, observations (observations) and the provision of response questionnaires were carried out to see the implementation and practicality of the AR learning media. The results of the second field trial found that the AR media had been declared to meet the criteria of usefulness and effectiveness. So, all forms of improvement were used as revision material, and the final product was obtained in the finalization.

Regarding the quality of learning media, the average score for the validity of AR-based learning media based on Balinese architecture is 3.68. The score is in very valid criteria so that the developed AR media meets the validity criteria. AR media can also be said to be practical because it can be seen from the recap of the learning implementation sheet. The results show a score of 3.02 in the limited trial, 3.28 in the field trial I, and 3.5 in the field test II. the last trial's average teacher response score to AR media in the field test I and field test II respectively, showed 3.67, which

was included in the very practical category, and 3.83, which was included in the very practical category. Based on the result data obtained from the implementation sheet, student response questionnaire, and teacher response questionnaire, it was found that the AR-based spatial geometry learning media developed had met the practicality criteria. Therefore, AR media is declared capable of meeting the effectiveness criteria. This result is indicated by the average score of the mathematics spatial ability test of class X IPA 5 and X IPA 6, respectively, which are 80 and 85. Both scores meet the established effectiveness criteria as being above the specified KKM (standard minimun in learning mathematics).

Students can improve their spatial abilities in terms of answers that match the concept of space geometry material. The achievement of indicators of students' mathematical spatial abilities is categorized into four, namely:

1) Identifying the shape or position of a geometric object viewed from a certain point of view.
2) Representing geometric models drawn on a flat plane.
3) Stating the position between elements in shape. Space at a certain point of view.
4) Investigating a geometric object.

Specifically, based on the questions/problems from the formulated sub-indicators, it was concluded that the spatial mathematical abilities of students at the 10th-grade high school level were in the medium category and had increased from before.

This research has succeeded in developing an AR-based spatial geometry learning media oriented to the concept of Architecture in Bali that is valid, practical, and effective; it also has characteristics that distinguish it from other learning media. The objectives and benefits of the research aim to determine the characteristics of ethnomathematical-based AR media that are valid, practical, and effective, as well as to know the characteristics of learning implementation when using AR media. AR media for teaching space geometry material has specific characteristics in the media and its performance.

The following will reveal the characteristics of AR media.

- AR media can display 3D objects and their animations as if they were in a natural environment and juxtaposed with information about two 3D things with added sound. It is hoped that it can be used as an alternative learning media to introduce the geometry of three-dimensional space.

- In AR media, students are given a lot of space for students to explore, imagine and make conclusions about three-dimensional space material. Students can directly see 3D visuals without having to guess them artificially. Students also collaborate with their group members to move the available markers, then try to conclude and answer the evaluations on AR media.

- AR media brings students to be enthusiastic about learning mathematics so that the level of student participation is higher in asking questions and using the AR media.

- AR media is also designed with simple object modelling, and there are guidelines so students can easily understand the storyline of using this application. The markers are presented sequentially, starting from the

initial concept of spatial geometry to the part to determine the exact distance and framework (nets).

- Students' AR media contains problems that relate to or are close to students' lives; namely, most students who live in Bali have bale men and bale dangin in their homes.

- AR media for students can directly contain studies of Balinese cultural values , namely getting to know the framework, illustrations, and even the uses of Balinese architecture.

- AR media facilitates and helps teachers streamline the meaningful learning process in the classroom. Teachers are used to anti-boring learning activities and use them as a reference for building independent schools.

- AR media contains alternative actions and is equipped with alternative answers to make it easier for teachers to direct students to the expected answers if students cannot understand and do the evaluation part of the AR application.

- The lesson plans are adapted to the learning process, namely in the form of activities synchronized with the developed media. Therefore, the RPP is designed to help teachers carry out learning using AR media provided by researchers appropriately.

The following also describes the implementation characteristics in the use of AR media. namely:

- AR media can be used as an alternative media during the mathematics learning process, especially spatial geometry. Students only download media on the link drive provided by the researcher, and previously students were required to check the memory space so that the application could be downloaded completely.

- When using AR media, students can explore 3D materials and shapes without needing internet access. Markers and materials are accessed only through the provided AR app. AR media integration as a filter will be carried out after obtaining approval from Spark-AR to be used in the Instagram application.

- Students bring up 3D objects, materials, and audio-only by scanning the markers prepared by the teacher. Students obtain 16 markers. The markers are in the form of cards, then used sequentially according to the number of the material discussed in class.

- The implementation of learning in class when using AR media is carried out by students in groups of 4-5. The marker scan activity is carried out simultaneously, with the teacher giving directions according to the instructions.

The weakness in this research lies in the problem of critical thinking skills. The questions in this study also need to be further revised so that they do not look similar to questions measuring student achievement. Questions are suggested to be presented more exploratively. Compulsory questions relate to more specific indicators of spatial ability, such as how when students see space from a different perspective, what if an area is cut into small parts, etc.

4. CONCLUSIONS AND RECOMMENDATIONS

This research has succeeded in developing AR-based spatial geometry learning media oriented to the concept of Architecture in Bali that is valid, practical, and effective. It also has characteristics that distinguish it from other learning media. The objectives and benefits of this research aim to determine the characteristics of Balinese architectural-oriented AR media that are valid, practical, and effective, as well as to know the characteristics of learning implementation when using AR media. Media Augmented Reality (AR) is very relevant to learning mathematics, especially the material geometry of space. The characteristics of AR media in this study are as follows. (1) AR media can display 3D objects and their animations as if they were in a natural environment and juxtaposed with information about two 3D objects with added sound. It is hoped that they can be used as alternative learning media to introduce spatial geometry. (2) In AR media, students are given a lot of space for students to explore, imagine and make conclusions about three-dimensional space material. Students can directly see 3D visuals without having to imagine them artificially. (3) AR media leads students to be enthusiastic about learning mathematics, so the level of student participation is higher in asking questions and using the media, etc. In addition, the characteristics of AR media, when used in the learning process, one of which is AR media, can be an alternative to spatial geometry media in overcoming the limitations of presenting material in schools.

The suggestions that can be given to further researchers are 1) the material can be further developed into a broader scope, 2) it is mandatory to consider if AR is used outside the Bali area so that the culture in Bali, especially the Balinese architecture, is introduced first. and 3) Teachers who intend to implement AR media should pay attention to the background conditions of students because using AR media requires gadgets to be able to access optimally.

CONFLICT OF INTERESTS

None.

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