Development of Interactive Media with Augmented Reality for Prospective Solution Quota-Friendly Learning and Physical Limitation in the Pandemic Era

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Abstract: *The problem in studying geometry for students with normal hearing and hearing impairment is that when studying geometry, it does not only require analytical presentations but also visual presentations related to spatial visualization abilities. This problem is getting worse during the pandemic, in which teaching and learning had to be done online. For this reason, it is necessary to have learning media that accommodates the characteristics of hearing impairment students that physiological limitations, and the media must be oriented to visual presentation accompanied by verbal descriptions or sign language so that the material presented is easy to understanding. The research and development model used in this study is the Borg and Gall procedural model which is descriptive and shows systematic steps to produce interactive learning media with augmented reality. The basis for choosing this development model is related to the special characteristics of the Borg and Gall development model, namely developing products to bridge the gap between education research and education practice, as well as emphasizing specific problems related to practical problems in teaching through applied research. Interactive learning media with augmented reality can be said to meet the criteria of validity, practicality, and effectiveness based on the results of testing the feasibility of developing products. The learning media used has also proven to be a solution to the problem of hearing limitations for hearing impairment students and internet accessibility problems, especially the problem of dependence on quotas and networks. So that students become more enthusiastic about learning and have a meaningful learning experience.*

Keywords: Interactive Media, Augmented Reality, Deaf Students, Quota-Friendly Learning

INTRODUCTION

The reach of the Coronavirus pandemic that occurred quickly and massively has expanded and affected various sectors of life, as in the health, economy, tourism, and education sectors (Sintema, 2020). The implementation of various activities must be carried out from home so that the chain of spreading the Coronavirus is broken, including learning activities (Kamsurya, 2020). The sector of education must adapt and try to transform suddenly through a face-to-face learning system by utilizing online communication and internet technology. This is following the circular letter of the Ministry of Education and Culture of Indonesia Number 4 of 2020 concerning the implementation of education policies in the emergency period of the spread of Covid-19 so that the learning process is carried out from home through distance learning.

The application of various learning platforms and applications have even emerged as the implementation of the learning policy at home, starting from the Learning Management System (LMS), Utilization of Learning Houses, SPAD, Zenius, Cisco to conference video are used to support learning from home including mathematics (Atsani, 2020; Gunawan et al., 2020; Irfan et al., 2020; Mailizar et al., 2020).

According to Atsani (2020), the problems during online learning during this pandemic are related to the unpreparedness of all components involved in the learning process, both in terms of standards and the quality of learning outcomes. Several other problems that arise along with the implementation of online learning have also been studied by several researchers such as Ali and Magalhaes (2008); Eady and Lockyer (2013); Hung and Chou (2015); and Karasavvidis (2010). As a result of these problems, it was found that students' boredom with online learning was found after the first two weeks of online learning, considerable anxiety to buy internet quota during online learning especially students whose parents had low incomes, as well as changes in students' mood due to too many assignments from the teacher (Irawan et al., 2020). In particular, the impact of Coronavirus pandemic on the online learning system was also investigated by Rasmitadila et al. (2020), Sintema, (2020), Sullivan et al., (2020), but only few studies have discussed certain about mathematics learning during pandemic (Mailizar et al., 2020). In fact, the implementation of a complex mathematics learning process during a pandemic is quite interesting to highlight because it requires accuracy delivering materials and developing mathematical skills (Santagata and Yeh, 2014).

Mathematics is a science with an abstract and hierarchical object of study, hence students need a sufficient learning experience that affects the process of acquiring knowledge to learn it (Andriyani and Maulana, 2019). One of mathematics branch whose objects is abstract, which is connected to other mathematical concepts and has a great opportunity to be understood/familiar by students is geometry (Andriyani and Dwi Juniati, 2019; Bell in Astutik, 2017; Clements and Sarama, 2011). Geometric objects are obtained through an abstraction process based on concrete objects found in daily life (Clements and Sarama, 2011; Couto and Vale, 2014). Some problems in studying geometry not only require analytical presentations but also visual presentations related to the ability of spatial visualization to understand properties and interpret two-dimensional images that represent three-dimensional objects. This spatial visualization ability is one of the geometry activities that must be mastered by students as recommended in The National Council of Teachers of Mathematics (NCTM, 1989). Therefore, visualization has an important role in learning mathematics, especially in problem-solving that requires complex cognitive management (Puloo et al, 2018).

Following the importance of visualization in solving problems, teachers need to pay attention to the development of these abilities in learning geometry using various contexts, especially the visualization of junior high school students (Puloo et al, 2018; Utomo et al, 2017). Junior high school students are children whose cognitive development is at the formal operational stage (12 years and over) so that their understanding of mathematical concepts has begun to lead to an abstract mindset. At this age, they also should be able to think logically without having to deal with direct objects or events (George, 2017; Ryandi et al., 2018). However, facts on the ground show that there are still many students who have difficulty in terms of geometry and visualization, including plane and solid shape, measurements, polygons, geometric ratios, geometric transformations, latitude, and longitude lines, and diagrams which are topics generally considered difficult by the students and teachers (Adolphus, 2011; Poch et al., 2015; Van Garderen et al., 2013).

The difficulties in learning geometry are also experienced by students with special needs, such as the hearing impairment who have physical limitations in terms of hearing and verbal communication (Buliali et al., 2021). This communication limitation affects the mathematics learning of hearing impairment students who are slower than their mates who can hear (Gottardis et al., 2011). In addition, hearing impairment also causes other obstacles such as inadequate knowledge, deficits in social skills, language delays, limited vocabulary and literacy, the emergence of background and domain knowledge gaps, also dependence on assistive technology (Luckner et al., 2012).

With various consequences of disabilities and difficulties in learning geometry, hearing impairment students who have curriculum content that is not much different from hearing students certainly experience obstacles when learning geometry is done online. According to Serianni and Coy (2014), students with disabilities experience additional online learning challenges related to their reduced motivation and accommodation, although by learning online they have the opportunity to access learning materials freely and repeatedly. Moreover, before COVID students with disabilities already had underperformance in mathematics compared to nondisabled students, in which affect to students' opportunities (Wei et al., 2013). Students with disabilities have less access to conceptual and challenging mathematics (Jackson & Neel, 2006). The trend towards inequality in opportunities to learn mathematics is more evident during Emergency Remote Teaching (Lambert and Schuck, 2021). Facts also show that many parents are unable to provide assistance according to student needs (Schuck and Lambert, 2020). This is supported by the results of research by Garbe et al. (2020) which shows that almost 10% of parents of non-disabled children have low motivation to engage online, thus hindering their child's learning. Several studies have found a decrease in student engagement during the online learning period in the general education (Kim et al., 2020) and among them are students with special needs (Balkist and Agustiani, 2020; Smith, 2020).

It is undeniable that online learning that has been carried out so far has not been able to fully facilitate interactive learning activities (Kamsurya, 2020), this is because communication between students and teachers during online learning is decreasing (Sintema, 2020). The lack of communication and direct interaction between teachers and hearing impairment students is an important problem that needs to be resolved and taken seriously. Moreover, hearing impairment students have difficulty interpretation formal definitions of geometry concepts, imagining spatial concepts, and relating contextual problems that contain geometry objects. The implication of this, hearing impairment students tend to memorize geometry concepts rather than understand geometry. The difficulty of students imagining abstract geometric objects certainly contradicts the condition of students' cognitive development at the high school level who should be able to reason without having to deal with direct objects. Meanwhile, the conditions of online learning and offline learning on a limited scale at this time, also make it impossible to provide direct experience to hearing impairment students. Besides the direct experience, according to Paranis and Samar (1982), the attention of students with hearing impairment is more quickly obtained by visual stimulation than others. This is reinforced by evidence that students with disabilities have better visual processing skills than hearing students (Musselman, 2000).

The existence of problems in learning geometry related to the special characteristics of hearing impairment students which have limited vocabulary in acquiring knowledge; difficulty in mental imagery to visualize the abstraction of geometry objects; and the inability to relate geometry concepts as a whole, it can affect student's ability to understand further mathematical material. Whereas referring to the Circular of the Minister of Education and Culture Number 4 of 2020, online learning must still provide meaningful learning experiences for students. This meaningful learning can be achieved by learning oriented towards providing direct experience related to the problems of everyday life. Therefore, appropriate strategies and methods of learning mathematics are needed so that students can have an understanding and ability to apply mathematics in daily life problems (Kamsurya, 2020).

To choose an appropriate learning method, teachers need to consider limitations, interest in learning, and whether the teaching materials used are interactive or not. According to Hasanah et al (2017), teaching materials used by teachers must facilitate the needs and accommodate the unique characteristics of students. As for hearing impairment students, more attention and significant changes in the learning paradigm are needed to improve the quality of their learning

(Adler et al., 2014). Learning conditions in schools which have very limited time and the use of teaching materials in the textual books form by teachers, the fact certainly influenced of hearing impairment student' learning motivation who feel increasingly different in obtaining access to educational services.

By considering the various problems of learning geometry, it is necessary to have a learning media that accommodate the characteristics of the hearing impairment who are more dependent on vision in the process of communicating and obtaining information during learning (Marschark et al., 2017). The media must be oriented towards visual presentation accompanied by verbal descriptions or sign language so that the material presented is easily understood by students. Augmented reality technology can be the best choice to facilitate hearing impairment students in understanding geometric abstract concepts through visual illustrations. According to (Buliali et al., 2021), augmented reality enriches students' perception of reality so that students' difficulties in imagining objects can be overcome by visualizing objects. In addition, augmented reality technology can also recognize physical objects to reveal their entities so that users can understand and utilize the properties of these physical objects (Ariso, 2017). This statement is reinforced by the statement of Pemberton and Winter (2009) which states that the use of augmented reality technology can support students' conceptual understanding and acquisition of information through group work and reflection on the direct experience they get. Thus, augmented reality becomes a new opportunity to support the mathematics learning process (Schallert and Lavicza, 2020). However, learning media using augmented reality technology for mathematics learning still lacking, especially in the geometry branch (Arifin et al, 2020).

Based on the problems experienced by hearing impairment students in geometry learning above, it is considered necessary and important to develop an interactive learning media that can support object visualization during geometry learning for hearing impairment students during the pandemic, but its media quota-friendly so that not cause student' anxiety. The interactive learning media developed in this study is an augmented reality technology-based learning media that contains the concepts of circles, transformations (rotations) and spheres to assist the spatial visualization of hearing impairment students in understanding the interrelationships of that three geometry concepts.

RESEARCH METHOD

This study is a research and development with the Borg and Gall procedural model, which aims to produce interactive learning media based on augmented reality that is valid, practical, and effective as a supporter of the learning model for mathematics teachers in schools with hearing impairments. This study's study procedure is part of the Borg and Gall model development procedure (Gall, 2003), consisting of five stages: developing a preliminary form of product, preliminary field testing, primary product revision, main field testing, operational product revision. Because this research is a follow-up study, the research and information collecting stage, the planning stage, have been carried out by researchers when conducting preliminary research related to needs analysis in the first year. Meanwhile, the operational field testing, final product revision, and dissemination and implementation stages could not be carried out due to time constraints and restrictions on school activities to prevent an increase in the transmission of the Covid-19.

At the stage of developing the preliminary form of the product, the researchers develop several things. They are preparing the initial design of the product which will be developed (hypothetical design); arrange necessary instruments during the research and development process; determine the stages of design test implementation in the field; determine the task description of parties involved in the research. While the preliminary field-testing stage is the stage of assessing the feasibility of the product by an expert accompanied by a limited initial field trial involving only two hearing impairment students. At this stage, the product feasibility assessment and initial field testing are reviewed from the substance of the design in terms of materials and media. The feasibility assessment and initial field testing are carried out repeatedly to obtain a feasible design. The next stage is the main product Revision. In this step, the researchers revise the design of the instructional media based on the results of expert assessments and limited field tests. The improvement of the initial media product here is mostly done with a qualitative approach so that the improvements made are internal because the evaluation is process-oriented.

After the researchers revise the media product, then the main field testing is carried out. In this step, the learning media product will be implemented in a wider scale learning, then the practicality and effectiveness of the learning media design will be tested. The research subjects involved in this study are 17 hearing impairment students. In this study, the practicality test of learning media is carried out through the provision of student response questionnaires, while the effectiveness test was carried out through experimental techniques.

The last stage of development media is the operational product revision stage. This stage is the second improvement after conducting a wider field test than the first limited field test. The improvement of the product from the results of this wider field test further strengthens the product developed, because the previously limited field trial phase is only involved, two students. In addition to internal improvements, this product improvement is based on the evaluation of the results so that the approach used is quantitative with comparing pretest and posttest. In detail, we present this development research procedure in Figure 1 below.

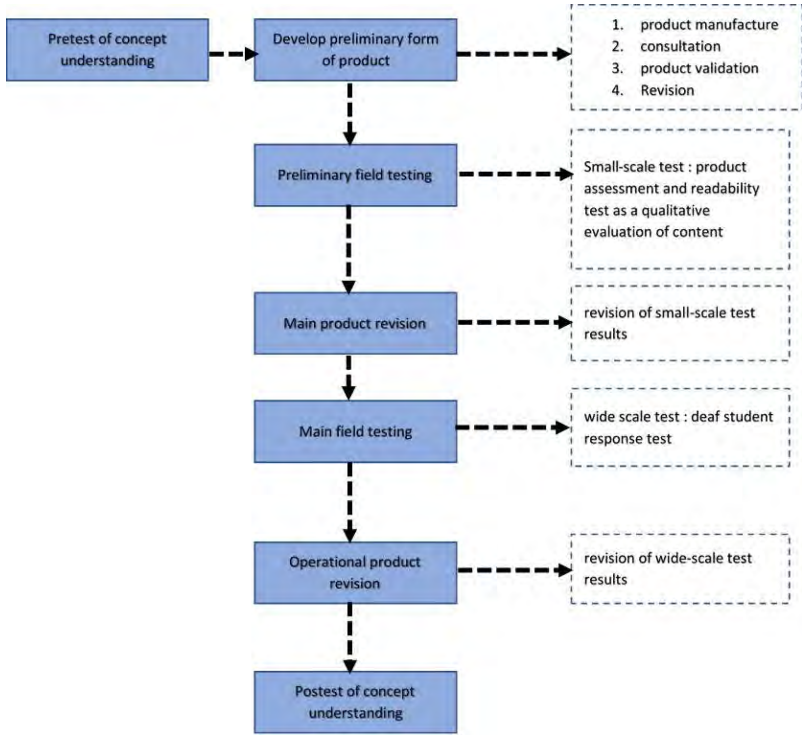


Figure 1. Research and Development section procedures of Borg and Gall

In this study, the population is all high school students with special needs for the hearing impairment, namely SLBN 2 Bantul, Yogyakarta. While the samples involved in the main field trial of this study are 17 hearing impairment students in grades VII, VIII, and IX and 2 hearing impairment students for a limited scale trial.

In this study, the media that has been developed will be assessed for feasibility in terms of validity, practicality and effectiveness. Therefore, this study data collection was carried out through test and non-test techniques. The test technique is carried out through giving pretest and posttest questions which consist of eight questions for understanding the concept of geometry to assess the effectiveness of the product as attached in Appendix 1. Non-test techniques are carried out through unstructured interviews, observation, giving student response questionnaires and giving product validation assessment questionnaires (material validation and media validation). Interviews were used to confirm and in-depth exploration, while observations were made to see student behavior during learning and taking tests. The provision of product validation assessment questionnaires and student response questionnaires resulted in two types of data, namely qualitative and quantitative.

Data analysis of questionnaires in this study was carried out qualitatively and quantitatively. The analyzed qualitative data of the validators' suggestions and students' suggestions descriptively. In line with the suggestions data, other qualitative data, namely the results of interviews and observation also analyzed descriptively. Whereas the quantitative data from validators and students, namely the scores from filling out product assessment questionnaires by validators and scores from filling out student response questionnaires. The questionnaires contain questions to measure expert opinion and student attitudes towards the products developed in this study. Answers from the validator and students indicate their level of agreement with a series of questions posed in the questionnaire. Approval on the questionnaires was arranged in stages using a Likert scale consisting of 5 choices as attached in Appendix 2 and Appendix 3. The score for each expert or student choice answer in a row is: 1) score 'Not Good' = 1; 2) score 'Less Good' = 2; 3) score 'Good Enough'=3; 4) score 'Good'=4; and score 'Very Good'=5. Of the five answer choice scores, the highest score = 5 and the lowest score = 1.

The results of the expert assessment questionnaire and the student response questionnaire were calculated on mean, next referred to as the actual mean score. The actual mean score obtained is then converted into the form of qualitative criteria which refers to the guidelines for determining the criteria of Azwar (2010) as presented in Table 1 below.

Table 1. Conversion of Qualitative Criteria

Score Intervals	**Category**
$R_i+1.5Sd_i<X_{bar}\leq R_i+3Sd_i$	Excellent
$R_i+0.5Sd_i<X_{bar}\leq R_i+1,5Sd_i$	Good
$R_i-0.5Sd_i<X_{bar}\leq R_i+0.5Sd_i$	Enough
$R_i-1.5Sd_i<X_{bar}\leq R_i-0.5Sd_i$	Deficient
$R_i-3Sd_i<X_{bar}\leq R_i-1.5Sd_i$	Very Deficient

Description:
X_{bar} = actual mean R_i = ideal mean
= ½ (ideal maximum score + ideal minimum score)
Sd_i = ideal standard deviation
=1/6 (ideal maximum score–ideal minimum score)
Ideal maximum score = number of questions × highest score
Ideal minimum score = number of questions × lowest score

Based on the conversion formula in Table 1, the interval difference for each actual mean score is obtained according to the number of questions on each questionnaire sheet as shown in Table 2.

Table 2. Actual Mean Score of Validator Assessment and Student Response

Score interval	Categories
Material Validation Assessment Questionnaire	
140<Xbar	Excellent
116.7 <Xbar≤140	Good
93.3 <Xbar≤116.7	Enough
70<Xbar≤93.3	Deficient
Xbar≤70	Very deficient
Media Validation Assessment Questionnaire	
92<Xbar	Excellent
76.7<Xbar≤92	Good
61.3<Xbar≤76.7	Enough
46<Xbar≤61.3	Deficient
Xbar≤46	Very deficient
Students Responses Assessment Questionnaire	
64<Xbar	Excellent
53.3<Xbar≤64	Good
42.7<Xbar≤53.3	Enough
32<Xbar≤42.7	Deficient
Xbar≤32	Very deficient

From the second interval the actual mean score obtained from the material and media validation assessment questionnaire, learning media products are considered valid if the actual mean score is in the minimally 'Good' category. The criteria for the practicality of learning media are also assessed in the same way namely, the actual average score obtained from the student response questionnaire is in the minimally 'Good' category.

In a different way, the analysis of the effectiveness of learning media products was carried out by comparing the pretest and posttest scores using SPSS. The comparison was carried out through the paired sample t-test mean, where the first mean showed the test results before the students were given the learning media and the second mean showed the test results after the students were given the learning media. The test used here is the statistical paired sample t-test. Before testing using the t-test statistical test, it is necessary to test for normality using the Shapiro Wilk test. After the data meet the normality requirements, the paired sample t-test is performed by comparing the significance values. If the significance value of the paired sample t-test <0.05, then H0 is rejected, so that augmented reality-based learning media is effectively used because there are differences in students' understanding of geometry concepts before and after using learning media. H0 is a condition where the mean pretest score is the same as the posttest mean score or there is no significant difference between the pretest and posttest mean scores. The opposite condition occurs if H0 is rejected.

Furthermore, to find out whether the use of learning media can be said to be effective or not, the researchers calculated the difference between the pretest and posttest scores (Gain score) using the N-Gain formula as a determinant of the category of the increasing students' conceptual understanding (Hake, 1999). The researchers also consider the mean posttest and pretest scores of students, which claims that an increase in the mean understanding of students' geometric concepts from before to after being given learning media occurs if the mean posttest score > the mean pretest score. The two N-Gain calculations and the consideration of pretest and posttest scores are used to base conclusions that the use of augmented reality-based learning media can be said to be effective in improving the understanding of geometry concepts for students with hearing impairment.

RESULT AND DISCUSSION

1. Develop Preliminary Form of Product Stage

At the stage of developing the preliminary form of the product, the researchers also compiled the instruments needed to see the feasibility of the learning media including namely, a material validation assessment instrument, a media validation assessment instrument, a student response questionnaire instrument, and an understanding test instrument. In addition, the researchers also compiled the initial design of the learning media that contained the circle material, the elements of the circle, its rotation, and the sphere. The initial design of learning media was based on the results of the needs analysis conducted in the initial research. Based on the results of needs analysis conducted by the researcher through observations and interviews in the initial research, there are some information obtained as follows:

a) Students with hearing impairment have difficulty understanding the material of a circle and its elements, so that when they learn the concept of a circle rotation they are increasingly constrained. As a result, the students have low understanding of several mathematical concepts related to the basic concept of a circle and it has implications in learning geometric concepts separately.
b) Students have difficulty translating formal definitions of circle and circle elements into pictures, so they always fail to visually imagine these abstract geometric objects.

c) The physical limitations of students with hearing impairment related to their hearing impairment make it difficult for them to communicate freely with anyone, without having to be constrained in mastering certain sign languages. In the end, these communication limitations have impact to their limited vocabulary and knowledge, especially mathematical knowledge that contains many symbols and abstract objects.
d) Mathematics teachers in special schools generally only use textual teaching materials as a source of student learning, such as textbooks. In the textbook there are many terms that students with hearing impairment do not understand when they present a formal definition of geometry. This learning resources that contain a series of writings do not attract students' interest in learning.
e) Geometry learning activities in class do not encourage student activity and are not related to students' daily life problems. In fact, many geometric models are found in the environment around students, so that in learning geometry such as circles, there should be a great opportunity to explore the surrounding environment by involving students' active participation through inquiry.
f) Students with hearing impairment need a learning media that can illustrate the formal definition of a circle and its elements, without having to load a series of texts and can visualize the abstract geometric objects so the students can easily imagine them.

From the results of the needs analysis in the initial research, the researchers developed a learning media designed with an image visualization display and oriented to students' interaction to facilitate the construction of knowledge. The learning media developed in this study contains a formal definition of a circle, elements of a circle, rotation of an object, and some results of the rotation associated with a 3-dimensional object, namely a sphere. The elements of a circle involved here are radius, diameter, arc, chord, sector, segment, and apothem. This learning media connects a concept of a 2-dimensional shape (circle and its elements) with a concept of the transformation geometry (rotation) of the 2-dimensional shape. Furthermore, the 2-dimensional shapes that undergo transformation are associated with the formation of 3-dimensional shapes due to the transformation events experienced.
To help students' spatial imagery, the learning media displays digital elements that can visualize these geometric abstract materials using markerless augmented reality technology. This markerless AR technology tracks real objects around students as marker objects, thus the media displays animated geometric objects in real time. Designing of learning media into application prototypes is carried out by Java programming language and openJL es, so the application can be implemented on Android. Furthermore, learning media in this form of applications can be used without internet connection access (offline). With application development using markerless augmented reality technology, the use of the application is free without having to create patterns or barcodes such as tracking objects. Specifically, the use of markerless augmented reality technology in the visual

application of a circle and its elements uses the Hough Circle Transform method to detect circle shapes and their elements. In addition to compiling research instruments and designing the initial learning media, the researchers also made a description of task plans that must be carried out in the next stages of development, including determining the stages of implementing the design test in the field as follows: 1) testing the feasibility of learning media with trials initial field with a limited number of subjects; 2) doing revision the design of instructional media based on expert advice and limited field testing; 3) providing a pre-test of concept understanding; 4) implementing learning media in learning on a wider scale; 5) providing response questionnaires to students; 6) making improvements based on student responses in a wide field test; 7) providing post-test understanding of the concept.

2. Preliminary field testing stage

This stage began with an assessment of the feasibility of the product in terms of the substance of material and media design by the validator. The assessment of the feasibility of each material and media product was carried out by three validators who have relevant expertise in the fields of learning materials, learning media and practitioners. The assessment of validity of the learning material by the material validators is presented in Table 3 below.

Table 3: Description of Learning Material Validity Assessment by Material Experts

Aspects	Validator 1	Validator 2	Validator 3
Introduction	36	34	40
Content	98	95	105
Closure	7	6	7
Actual Mean	**141**	**135**	**152**
Overall Actual Mean		**142,67**	

Based on analysis of material expert validation result, it is known that the actual mean score of the material validator 1 is 141 with the "Excellent" category, the actual mean score of the material validator 2 is 135 with the "Good" category, while the actual mean score of the material validator material 3 is 152 with the category " Excellent ". The overall actual mean score of the three material validators is 142.67 with the " Excellent" category. Thus it can be concluded that the learning media developed in terms of material is declared valid or feasible to use. The assessment of validity of the learning media by the media validators is presented in Table 4 below.

Table 4: Description of Learning Media Validity Assessment by Media Experts

Aspects	Validator 1	Validator 2	Validator 3
Introduction of Application	10	10	`12
User control	23	20	25

Application View	50	40	52
Principles of Multimedia Design	19	18	15
Actual Mean	**102**	**88**	**104**
Overall Actual Mean		**98**	

Judging from the actual mean score of media validator 1 is 102 in the " Excellent" category, the actual mean score of media validator 2 is 88 in the "Good" category, while the actual mean score of media validator 3 is 104 with the category "Excellent". The overall mean score of the three media validators is 98 in the "Excellent" category. Thus, it can be concluded that the learning media developed in terms of media is declared valid or feasible to use. In terms of materials and media, it can be concluded that the augmented reality-based interactive learning media developed in this research has met the criteria for validity of a development product.

Beside of providing an assessment to the validator, the researchers tested the learning media on a limited basis to get input from the test subject. The mathematics teacher at SLBN 2 Bantul randomly selected two students with hearing impairment as subjects for a limited trial. Researchers tested the media as long as students participated in learning activities using augmented reality-based interactive learning media. After the students had a learning experience with the learning media, the researcher required them to fill out an assessment sheet and students' impressions while using augmented reality-based interactive learning media. From the results of the assessment and impressions of students in the small-scale trial class, it is known that there are no significant problems with the use of augmented reality-based interactive learning media. Students found it a little difficult to distinguish writing from real backgrounds in the form of objects in the surrounding environment, so the researcher needs to improve the color contrast of writing on learning media.

3. Main product revision stage

At this stage the researchers revised the design of the learning media based on the results of expert assessments and limited field tests. Based on the suggestions of the two students in the small-scale trial, the researchers changed the color of the writing that accompanies the description of the object image display of the learning media so that it is easy for students to read. The researchers also revised the design of learning media based on some suggestions of the validators. The improvement of the initial media products here is more related to the size of the letters that appear on smartphones and the delay in presentation between materials.

4. Main field testing stage

After revising the media product according to the suggestions of the validators and the test subjects, the researcher implemented the learning media on a wider scale to test the practicality and effectiveness of the instructional media design. The research subjects involved in the implementation of this development product were 17 students with hearing impairment.

Researchers used augmented reality-based interactive learning media in learning activities of circles, elements of circles and their rotations. The researchers provided a series of implementations of the implementation of learning media in the seventeenth grade students as below.

First Meeting Activities

The researchers gave pretest questions to find out the students with hearing impairment' initial understanding of the circle material, its elements and, rotations before learning using learning media. The pretest consisted of 8 essay questions with an allocated time of 90 minutes. Students worked on pretest questions at school by implementing a strict health protocol by the school.

Second-Third Meeting Activities

The second meeting was held at SLBN 2 Bantul by implementing a strict health protocol. The researchers started the lesson by motivating students before learning the basic concept of a circle by explaining the importance of learning the material related to everyday life. The purpose of learning at this meeting is to understand the formal definition of a circle which was previously only able to be memorized by students. Before starting the student activity to understand the definition of a circle, the researchers divided the students into several groups with each group consisting of three students. Then, the researchers distributed one smartphone each that had the markerless augmented reality application installed to group representatives and introduced the use of the learning media to students.

The learning activity began with exploring objects around students to detect which ones were circular and not circular. This activity is to stimulate student activity through investigation and concept discovery with direct experience. Figure 2 (a)-(b) shows the exploration of surrounding objects by students in groups.

Figure 2 (a)-(b). Students are exploring objects around them using augmented reality media

A display of circular objects recognition on real objects explored by students is presented as shown in Figure 3 below.

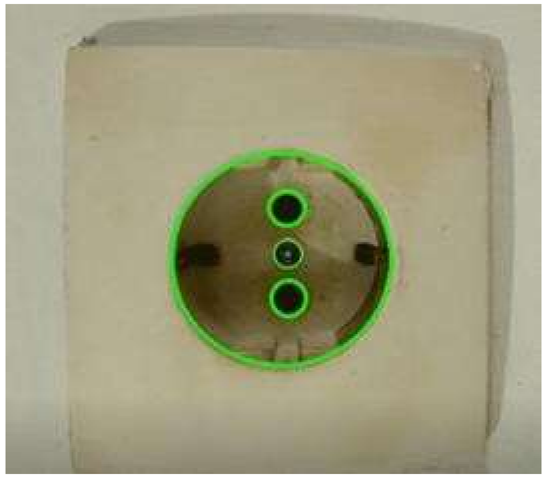


Figure 3. Recognition of circular objects with markerless augmented reality

If the object detected by the student is in the form of a circle, the learning media will automatically display a green circle marker as shown in Figure 3 above. Detection of a circle shape is followed by the presentation of a formal definition of a circle consisting of two definitions. The first definition relates to a circle as a simple closed curve as shown in Figure 4 below.

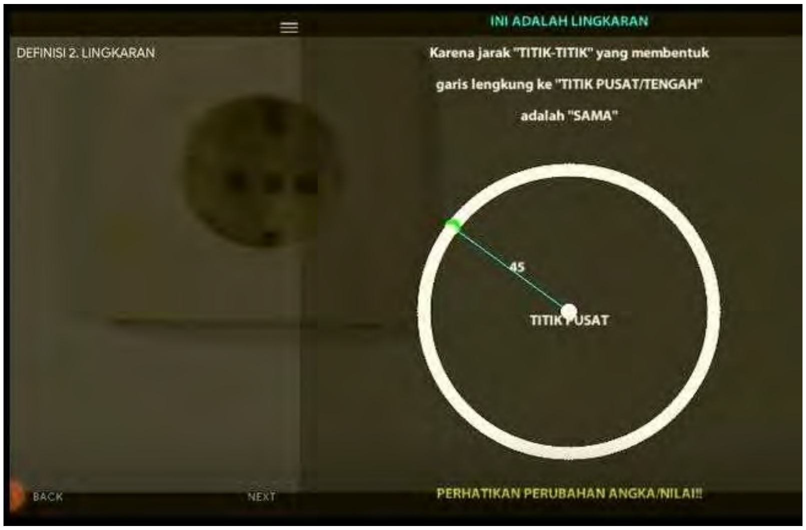
DEFINITION 1: CIRCLE

THIS IS A CIRCLE
Because it consists of a "SET OF POINTS" that constructed a "CLOSED CURVED LINE"

THIS IS A CIRCLE
Because it consists of a "SET OF POINTS" that constructed a "CLOSED CURVED LINE"

Figure 4. The first definition relates to a circle as a simple closed curve

The second definition relates to a circle as a set of points that are equidistant from the center as shown in Figure 5 below.



DEFINITION 2: CIRCLE

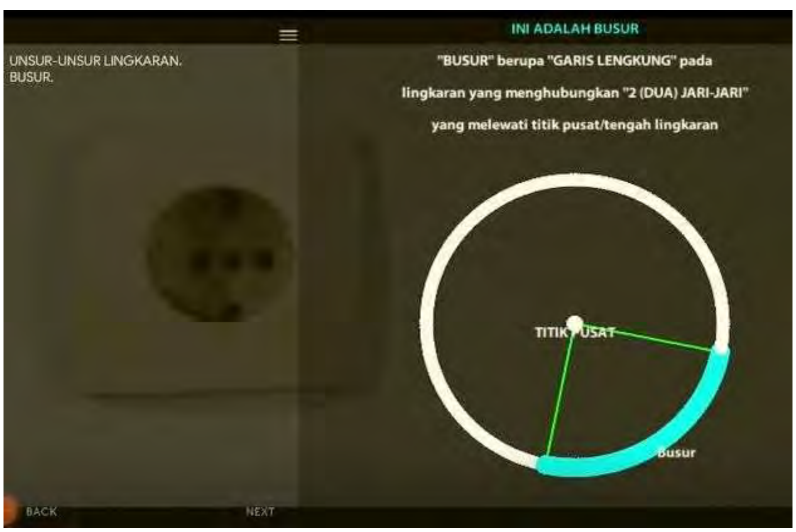
THIS IS A CIRCLE

because the distance of "POINTS" that constructed a curved line to "CENTER/MIDDLE POINT" is the same

PAY ATTENTION TO CHANGES OF NUMBERS/VALUES !!!

Figure 5. The second definition of circle relates to a set of points equidistant from the circle center

After presenting the definition of a circle, students can continue learning by choosing what circle elements they wanted to learn. The selection of the circle element that appears on the student's smartphone screen is accompanied by an example of a concept and not an example of a concept, while an example of circle element display is shown in Figure 6 (a)-(d).



CIRCLE ELEMENTS.
ARC

THIS IS ARC

"ARC" is "CURVED LINE" on the circle relating "2 (TWO) RADIUS" passing through the circle center/middle point

Figure 6 (a). Visualization of an example of an arc as a circle element

CIRCLE ELEMENTS.
ARC

THIS IS NOT ARC

because the "CURVED LINE" doesn't connect "2 (TWO) RADIUS" and doesn't pass through the circle center/middle point

Figure 6 (b). Visualization is not example of an arc

CIRCLE ELEMENTS.
APOTHEM

THIS IS APOTHEM

"APOTHEM" has the shape of "LINE SEGMENT of PERPENDICULAR" relating "CENTER" with one point in "ARC POINT"

Figure 6 (c). Visualization of an example of an apothem as a circle element

CIRCLE ELEMENTS.
APOTHEM

THIS IS NOT APOTEMA

Because the "LINE SEGMENT" that connecting "CENTER" with "A POINT on THE CHORD" is not "PERPENDICULAR"

Figure 6 (d). Visualization is not example of an apothem

The presentation of examples and not examples of concepts presented in this learning media is in accordance with the achievement of indicators of understanding exemplifying and interpreting as presented by Anderson & Krathwohld (2001).

After exploring what objects were circle-shaped and observing the appearance of the elements of the circle, students wrote down all the results of their investigation and concept discovery with the guidance of the teacher as shown in Figure 7 (a)-(b) below.

Figure 7 (a)-(b). Students are exploring objects around them using augmented reality media

Fourth Meeting Activities

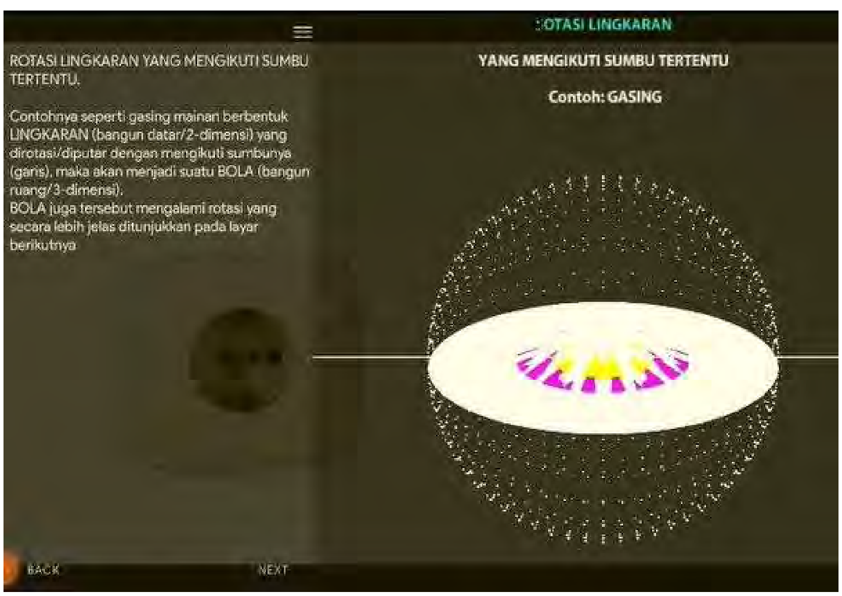
At this fourth meeting, students continued learning about the rotation of a circle and a sphere. By choosing any object that was detected as a circle, students selected rotation menu and observed the rotation display of a circle with a certain angle and a sphere on the smartphone screen that had been distributed by the researcher. The view of the rotation of object (circle) and the sphere is presented as in Figure 8 (a)-(b) below.

ROTATION AND ANGLE OF ROTATION

ROTATION

It is a location change of an object (point) by rotating through a center of rotation and a particular center angle.

Figure 8 (a). The rotation of object and angle of rotation



CIRCLE ROTATION THAT FOLLOWS A SPECIFIC AXIS

For example, a Gasing toy in the shape of a CIRCLE (Plane figure/2-dimensional) in which will rotated following the axis (line) will become a SPHERE (building a 3-dimensional space).
The SPHERE also rotates.

CIRCLE ROTATION THAT FOLLOW A SPECIFIC AXIS

Example: GASING TOU (Frees-bee)

Figure 8 (b). The circle rotation become a sphere

Fifth Meeting Activities

After learning the circle material, elements of circles, rotations and sphere, the researcher gave a response questionnaire to the seventeen students with hearing impairment. The provision of student response questionnaires was carried out to test the practicality of learning media. Based on the results of the student response questionnaire, it is known that there is one student who categorized the interactive learning media with augmented reality as "Good" and there are sixteen other students who categorized the media as "Excellent". The actual mean score of the results of the responses of students with hearing impairment who became users of learning media is 67.66. This means that the mean is in the "Excellent" category, so that the learning media can be said to have met the criteria for the practicality of a product development.

5. Operational product revision stage.

At this stage the researchers made improvements based on student responses in a wide field test. The product improvement from the results of this wider field test was used to further strengthen the product being developed. Next, the researcher gave a posttest related to students' understanding of the concept after being given learning media. The results of the posttest carried out by the researcher would then be compared with the results of the pretest that had been carried out before the main field testing stage was carried out. Comparison of the results of the pretest and posttest of the seventeen students was carried out to assess the effectiveness of the learning media by using the test questions that can be seen in Appendix 1. Before testing the two test results, the researcher tested the normality of the data using Shapiro Wilk test. From the results of testing the normality data for the pretest, it is obtained significance value (p-value) = 0.643 and for the posttest data it is obtained a significance value (p-value) = 0.464. Because the p-value of the second test is > 0.05, the data meets the requirements for normality of the distribution data. Then, paired data test was performed using paired sample t-test with SPSS software.

Based on the paired sample t-test, it is obtained that the significance value (p-value) = 0.004. Because p-value < 0.05 then H0 is rejected. In other words, there is a significant difference between students' understanding of geometry concepts before and after using learning media according to the results of testing the pretest and posttest scores. Besides, the researcher also compared the average understanding of students at 57.50 and the posttest at 76.38. Because the mean posttest score > the mean pretest score, it can be said that there was an increase in students' understanding after using learning media. Next, the researcher calculated the N-Gain value of the students with hearing impairment ' understanding. From the results of the calculation on the pretest and posttest, students obtained a score of 0.45. This shows that the increase in students' understanding is in the moderate category. In other words, the learning media developed in this study is effective in increasing the concepts understanding of students with hearing impairment who previously had difficulties and were constrained in learning due to physiological and accessibility to the internet network limitation.

The effectiveness of Augmented Reality learning media in improving students' understanding is in line with the research results of Coimbra et al (2015) which shows that augmented reality can encourage higher motivation, understanding and interaction with the material being studied. This effectiveness is an indicator of the breadth of use of augmented reality and the magnitude of its potential in education (Garzón et al., 2017; Yu et al., 2009). In particular, the effectiveness of augmented reality-based learning media in geometry learning is also seen through increasing of students' mathematical spatial abilities (Arifin et al, 2020).

Regarding to the practicality of learning media, which refers to the results of the student response questionnaire (very good), it shows that students with hearing impairment accept the use of augmented reality-based learning media in their learning very well. Based on the results of observations and interviews, the students even seem more enthusiastic about learning because they no longer have to depend on the existence of internet quotas. The enthusiasm of students with hearing impairment in learning, which is also seen from student responses during learning, shows that learning media innovation with augmented reality can be accepted because it utilizes smartphones as a technology that is close to students. This is supported by Setyaningrum and Waryanto (2018) which states that the use of smartphones in classroom learning increases students' motivation and learning outcomes. One of the applications that are suitable to be developed on smartphones is augmented reality (Guntur et al, 2019).
Enthusiasm and increasing understanding of the concept of students with hearing impairment when using augmented reality-based learning media, also shows the important role of technology in student interaction and better performance during mathematics learning as stated by Panthi et al (2021). The use of such technology also reduces the abstraction of learning and creates an environment that is suitable for students' life situations (Dikovic, 2009). With this, Dikovic (2009) adds that the exploration of Information and Communication Technology (ICT) encourages student engagement and motivates them to leave rote-based learning. Likewise, the appropriate use of ICT positively encourages more interaction between teachers and students, resulting in better collaborative outcomes (Koc, 2005). Furthermore, Koc (2005) clearly explains that the usefulness of ICT enables the students to communicate, share knowledge, and work collaboratively anytime and anywhere. In this case, students not only get knowledge together but also mutually share diverse learning experiences with each other. Moreover, if the use of ICT is applied to learning during a pandemic, then its use supports effective learning from home whose teaching requires mastery and the application process of many parents who are not necessarily able to do so (Gay, 2002).

Seeing the significant role of augmented reality-based interactive learning media, the use of this media as a complement to the learning of students with a hearing impairment needs to continue even though it is not in a pandemic condition. In fact, it can also be used by students with normal hearing as an alternative learning tool. The use of augmented reality as an additional learning tool for all students is also in line with the research results of Guntur et al. (2019). Furthermore, in his research, Guntur also stated that most of the teachers who participated in the augmented reality development training agreed with applying this technology in classroom learning because it would help teachers improve their students' affective and cognitive abilities. Thus, the use of augmented reality-based interactive media is one of the answers to the implementation of a non-discriminatory information and communication technology-based learning system.

CONCLUSIONS

Interactive learning media with augmented reality can be said to meet some criteria of validity, practicality and effectiveness based on the results of product development feasibility testing. The validity of the learning media is shown by the fulfillment of the excellent category in terms of material with the mean validation score of 142. 67 and the excellent category in terms of media with the mean validation score of 98. The practicality of the learning media is shown by the fulfillment of the excellent category in terms of student responses with the mean score is 67.66. For the effectiveness of learning media, it is shown by the significant difference between the pretest and posttest scores for the understanding ability of hearing impairment students. Finally, the mean posttest score is greater than the mean pretest score, which can also be seen from the increase between the pretest and posttest scores in the moderate category. Therefore, the learning media used has proven to be a solution to the problem of limited hearing for students with hearing impairment and internet accessibility problems related to the availability of internet data balance and networks.

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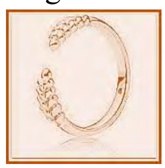
APPENDIX 1. PRETEST and POSTTEST

Answer the following questions well!

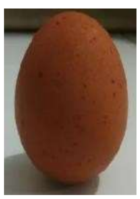
1. What is circle in your opinion? Give an illustration and explanation about the circle!
2. Give examples of objects that are circle models and models that aren't circles according to your knowledge and give the reason!
3. Which of the following images contains circle model?


(a)


(b)


(c)


(d)


(e)

(f)


(g)


(h)

4. Mention what you know about elements or parts of circle based on books you have read?
5. Take a look at the following bike picture.


(source: pulsk.com)

(a)


(source: dawaihati.com)

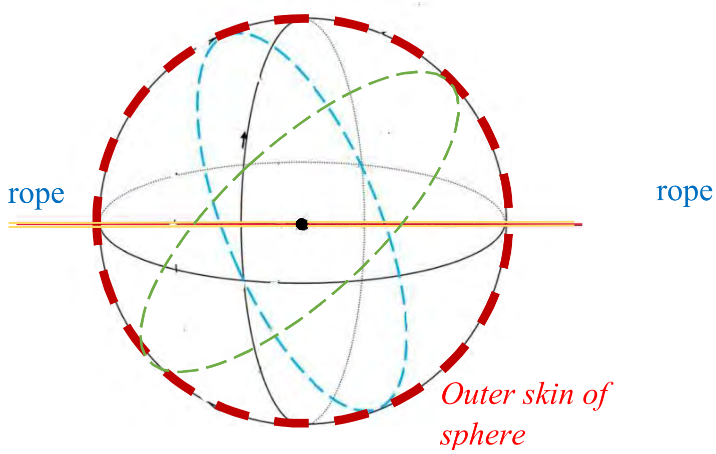
(b)

Which of the two bikes do you think you would choose to ride? Give me a reason for choosing this bike!

6. A coin rolled on a flat floor will turnaround. What do you know about the rotation of a circle?
7. An object that is rotated at a certain direction and angle, will definitely change the position of the object. What do you think about its position after the object has been rotated? Try to show it by your own way!
8. Suppose a color circle is rotated with its center point is the center point of the circle connected by a rope as in the following image.

(source: kesekolah.com)

If the rope is moved in various directions on a regular basis, then the circle will rotate and leave a trace of a red sphere skin as in the image below.



What can you infer from this experiment?

APPENDIX 2.

AUGMENTED REALITY (AR) INTERACTIVE LEARNING MEDIA VALIDATION SHEET BY MEDIA EXPERT

A. PURPOSE

To measure validity of Augmented Reality Interactive Learning Media of application introduction quality, user control, application view, and principles of multimedia by media experts.

B. INSTRUCTIONS

1. To Messrs./Mmes. please give an assessment by giving a tick (√) in the column that has been provided, in accordance with the following assessment criteria:
   1: Not Good
   2: Less Good
   3: Good Enough
   4: Good
   5: Very Good
2. To Messrs./Mmes. please give advice for improvement by writing on the comment line and suggestions that have been provided.

No	Assessment Criteria	Score				
		1	2	3	4	5
Introduction of Application						
1	Ease of application title in providing an overview of the application					
2	Clarity of operating guidance and the displayed menu					
3	How attracting the view of the learning media design					
User control						
4	Control sequence accuracy					
5	Consistency of navigation button layout					
6	Smooth use without hang, crash or lag					
7	Use of media on the Android platform flexibility of time and place of usage					
8	Interactive AR learning media					
Application View						
9	Consistency of layout proportions (text and image layout)					
10	Accuracy of background selection					
11	Consistency of colors use					

12	Consistency of selection of text types and fonts presented					
13	Consistency of text size selection presented					
14	Icons and navigation buttons are easy to understand					
15	Consistency of use of icons as navigation buttons					
16	Suitability of the animation used in the material					
17	Accuracy of presentation of audio replacement writing					
18	Video display quality and length of video duration					
19	Suitability of video use with material					
Principles of Multimedia Design						
20	Presentation of material using more than one medium					
21	Presentation of material using words and images/animations/videos side by side (not separately)					
22	Use of images, writing and animations that are interrelated only (negating unrelated and relevant information)					
23	Presentation of material using media in a non-excessive manner					

Comment and Suggestion:
…………………………………………………………………………………………………
..……………………………………………………………………………………………..
…..…………………………………………………………………………………………..

C. CONCLUSION

In terms of media aspects, Augmented Reality Interactive Learning Media, stated:
1. Worth using
2. Worth using after revision
3. Not worth using

Please circle the choice of numbers that have been provided in accordance with the conclusion as a whole.

..........., ……………… 2021
Validator,

………………………………..…

AUGMENTED REALITY (AR) INTERACTIVE LEARNING MEDIA VALIDATION SHEET BY MATERIAL EXPERT

A. PURPOSE

To measure the validity of The Interactive Learning Media of Augmented Reality based on the aspect of introduction, content, and aspect to closure by material experts.

B. INSTRUCTIONS

1. To Messrs./Mmes. please give an assessment by giving a tick (√) in the column that has been provided, in accordance with the following assessment criteria:
   1: Not Good
   2: Less Good
   3: Good Enough
   4: Good
   5: Very Good
2. To Messrs./Mmes. please give advice for improvement by writing on the comment line and suggestions that have been provided.

No	Assessment Criteria	Score				
		1	2	3	4	5
Aspect of Introduction						
1	Clarity of learning instructions					
2	Clarity of learning achievement					
3	Clarity of the description of the concept map of the material studied					
4	Clarity of 3D images in introducing the concept of circles and their transformations					
5	Clarity of the appearance of a 3D image of a circle and its transformation in the user's point of view in real time					
6	Learning media contains pattern recognition on objects					
7	The suitability of a 3D image to represent a model of a circle and its transformation					
8	Conformity of material in the learning media with Core Competencies and Basic Competencies					

9	Conformity of the material with the purpose of learning					
10	Conformity of material content with standard concepts					
Aspect of Content						
11	Traceable contents/material description					
12	Coverage (breadth/depth) of material					
13	Factual material					
14	Actualization of material					
15	Example clarity included to clarify content					
16	Clarity and suitability of the relevance of the language used					
17	Material suitability for students' cognitive characteristics and development					
18	Material contained in the media provides new knowledge and stimulates the mathematical ability of students.					
19	Clarity of instructions for completing a learning task					
20	The attractiveness of the instructions presentation to stimulate students' thinking activities					
21	Accuracy of giving feedback on learning achievements					
22	Conformity of sentence use with the intellectual level of the student					
23	Ease of use of the terms					
24	Consistency usage of text					
25	AR learning media facilitates the introduction of abstract concepts that are difficult to realize in real / direct					
26	AR learning media attracts user attention and motivation					
27	The function of AR learning media is to reinforce students' understanding and spatial abilities					
28	Learning material directs students to do exploration of around objects students					
29	Learning material directs students to do knowledge discovery					
30	Efficiency usage of language					

31	Suitability the sentence with good and correct language rules					
32	Completeness of information					
33	Detail and completeness of content					
Aspect of Closure						
34	Clarity of interrelationships between concepts as a whole					
35	Clarity of summary as looping material					

Comment and Suggestion:
…………………………………………………………………………………………………
..……………………………………………………………………………………………..
…..……………………………………………………………………………………......

C. CONCLUSION

In terms of material aspects, Augmented Reality Interactive Learning Media, stated:

1. Worth using
2. Worth using after revision
3. Not worth using

Please circle the choice of numbers that have been provided in accordance with the conclusion as a whole.

..........., ……………… 2021
Validator,

………………………………......

APPENDIX 3.

INTERACTIVE LEARNING MEDIA ASSESSMENT SHEET AUGMENTED REALITY (AR) BY STUDENTS

A. PURPOSE

To measure the practicality of Augmented Reality Interactive Learning Media through student response after using it.

B. INSTRUCTIONS

1. To students, please provide an assessment by giving a check mark (√) in the colum that has been provided, in accordance with the following assessment scale criteria:
   1: Not Good
   2: Less Good
   3: Good Enough
   4: Good
   5: Very Good
2. To the students, please give an impression by writing on the column that has been provided.

No	Assessment Criteria	Score				
		1	2	3	4	5
Ease of Application Usage						
1.	Clarity of application usage instructions					
2.	Symbols and buttons are easy to understand					
3.	Ease of running the application					
Application View						
4.	Color composition does not interfere.					
5.	How interesting the application background color					
6.	Text layout accuracy and background with text color					
7.	Compatibility and harmony of the selection of typefaces, size and spacing of spaces between writings					
8.	Suitability and attractiveness the use of image and video					
9.	Balance between text and video use					
10.	Regularity of the location of components (icons, navigation) of applications					

Ease of Application to Learn Its Contents						
11.	Clarity of learning achievement and goal					
12.	Attractiveness and the systematic of material presentation					
13.	Use of sentences and grammar to support an understanding of the material					
14.	Text readability in terms of text type and size					
15.	Setting examples to support an understanding of the material					
16.	Use of text, images, and video/animation to support an understanding of the material					

C. IMPRESSION

Yogyakarta, ...2021
Student

....