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Developing an augmented reality based interactive module for lessoning curvent side space building

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ABSTRACT

In previous research, it was found that the incorporation of AR technology has the potential to improve the way people learn in curved spaces and make it easier for students to visualize shapes. This makes a solution to the problem of students found by researchers in the field that students find it difficult when learning curved spaces without the help of props. However, students also say that the use of physical form props is not practical to use. Therefore, the goal of this research is to develop valid, effective, and practical augmented reality-based interactive learning materials for use in curved space learning. This product is developed using the ADDIE model. Data were collected through student response questionnaire instruments and pre-test post-test questions. Data analysis was conducted to determine the validity of the product using the Aiken Value, the level of effectiveness obtained through the n-gain score, and practicality using the mean value and TCR of the student response questionnaire score. It was found that the product was classified in the "high validity" category from material experts as well as media experts. For the level of product effectiveness, the results obtained are "moderately effective" and for the level of practicality, the product is declared to have "good" practicality.

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INTRODUCTION

The fact that technological progress has been embedded in our lives has prompted investigations into the possibility of using technology to improve the quality of education (Al-Azawi et al., 2019). The significant impact of the rapid development of information and communication technology has made learning activities changeable and modern (Demitriadou et al., 2020). AR is the most frequently used technology in learning and this technology is in the form of virtual content that is shown in three dimensions in real time (Hanid et al., 2022). AR uses a system connected to a smartphone or other device (Ahsan et al., 2020).

The term Augmented Reality was first coined in the 1990s by Professor Tom Caudell when he was working at Boeing Computer Services' Adaptive Neural Systems Research and Development Project in Seattle. While working there, he gave his name to a tool attached to the head of a worker with the purpose of helping workers inspect the electrical wiring on planes. Augmented reality is defined as the intersection of virtual and real objects so that the resulting digital visuals can be combined with the real world and can help provide user perception (Kumar et al., 2021). Examples of AR use have existed since 1968, although the technology available at the time was large and immovable. In addition, the device was expensive, a far cry from the situation today with the proliferation of affordable, practical and accessible mobile devices such as smartphones and tablets (Walker et al., 2017).

It has been found that the use of AR technology shows potential when applied in topics such as geometry which is one of the materials in mathematics lessons (M. Akçayÿr & G. Akçayÿr, 2017). In Cahyono et al., (2020) and Cabero et al., (2017) mention that the potential in AR applications can be harnessed to increase student engagement and the quality of mathematics learning. The amount of student participation in the learning process can be reliably supported by using AR and it can even increase the intensity of the teacher's ability to build learning and teaching activities, it can also provide an experience that will be enriched through the learning space. by stimulating a conducive and active learning atmosphere in addition to being able to convey experiences from deeper academic content (George Reyes, 2020).

the implementation of AR in mathematics education works to make learning interesting and interactive. One of the main benefits of AR technology is that it can integrate the AR world with the real world based on student experience which means that students can achieve a greater sense of realism towards visual forms in the virtual environment they are in (Miundy et al., 2019). There are clear benefits of augmented reality technology in the field of education as material to energize and motivate students because the material is presented in an engaging way, a way that suits the current digital age. (Majeed & ALRikabi, 2022).

The researcher made observations in the field and asked some questions or short interviews with teachers and students. According to the mathematics teacher, students are very happy to do learning activities using learning media because according to students, learning with integrated media becomes easier to understand and increases curiosity about the material being studied. In addition, learning with the implementation of media according to teachers can improve student learning outcomes. Based on what the teacher delivered, during the learning of the curved side space, learning media such as PowerPoint and three-dimensional space props were used. However, using new educational media for students, interactive, creative, and innovative requires a variety of options for using learning media so that students are not bored and then can be adjusted by using which learning media to make the right choice. used and appropriate to the material to be discussed.

In a brief interview with the students, they (students) said that in learning spatial building materials, they need the ability to imagine shapes well. When students do not have props to help display the room model, students find it difficult to solve problems and learn the material. Another obstacle felt by the students is that the school does have three-dimensional space building props, but the students do not have them at home. Therefore, if students make/buy props even if they are small or can be taken anywhere, they still feel reluctant to take them anywhere if props are needed such as when going to school and returning home because students sometimes forget to bring prop.

The problems found by researchers in the field are in line with the findings of the investigation by Ramdhani et at.,(2017) that there are a few students who experience difficulty in solving geometry topic problems because the content of the topic is considered abstract so that it can affect low academic achievement in Mathematics subjects. This finding is in line with the opinion of many scientists, that in mathematics and geometry, students often cannot draw the relationship between 3D objects in the form of two-dimensional images with real-life embodiment, and as a result have difficulty distinguishing solid geometry from flat shapes (González, 2015). As the study Yip et al., (2018) states that students with low visual abilities have the potential to experience difficulties in developing the visualization of spatial shapes.

The obstacles in learning curved space described in the previous paragraph can be overcome by using AR in learning. There has been a lot of research and development of AR-based learning media in mathematics learning, such as research by Dinayusadewi & Agustika, (2020) which can be concluded that AR can be used as a tool for geometric concepts in school. AR-based research was also conducted by ÿbili et al., (2019) by developing an AR Geometry Tutorial System (ARGTS) to improve 3D geometric thinking skills. According to research conducted by Ferrer-Torregrosa et al., (2015) AR has the capacity to provide better spatial understanding and help students get better grades for individual writing assessments compared to traditional methods. In Ivan & Maat, (2024) AR technology can improve conceptual understanding to improve student learning outcomes. Several studies confirm that AR has high relevance for 21st century students(Kellems et al., 2020).

The results of previous studies confirm that the use of AR in learning can facilitate the learning and teaching of geometric materials. However, not many designs AR-based learning media in the form of textbooks (modules) or e-books with AR usage instructions. The integration of AR technology in the interactive module is designed to improve the representation and visualization of curved spaces. Based on the description in the previous paragraph, this development study aims to develop learning media in the form of AR-based interactive modules that are valid, effective, and practical in order to help students in learning curved space building materials and can be used as needed, can be used in the form of physical books or e - books.

METHOD

The development model used in this development research is ADDIE which consists of 5 stages namely analysis, design, development, implementation and evaluation. The first stage is the analysis which consists of three stages of analysis which are: (1) Analysis of needs; (2) Concept analysis; (3) Task analysis. The second stage is the design which consists of three stages namely: (1) Preparation of material content; (2) Creation of AR content, images/decorations and animated videos of curved lateral space nets; (3) Determination of product manufacturing media.

The third stage is development, at this stage the implementation of the design that has been designed in the previous stage is carried out. Once the product is finished, it will be tested by 2 material experts and 2 media experts to find out the level of validity that will be used in the research. Aspects of evaluation by content experts are feasibility of content, feasibility of presentation, and use of language. In terms of graphics, there are evaluation indicators consisting of module size design evaluation, content skin design, and content design. In the process of product validation by experts, the product receives evaluation, criticism, and suggestions that the researcher then improves the product according to the validator's revision. Furthermore, products are referred back to experts until they gain a status worthy of use in research without or with review. Product evaluation scores by experts are calculated using the Aiken Value to find out the average CVI (Content Validation Index) so that the level of validity can be interpreted.

In Guilford et al., (1978) the interpretation of average CVI values is classified in Table 1.

Table 1. Interpretation of CVI Values

Interval Value	Interpretation
0,80 < CVI ≤ 1,00	Very High
0,60 < CVI ≤ 0,80	High
0,40 < CVI ≤ 0,60	Moderate
0,20 < CVI ≤ 0,40	Low
0,00 < CVI ≤ 0,20	Very Low

The fourth stage is implementation, the product produced will be tested on the study subjects. Product trials consist of limited trials and extensive trials. The experiment was conducted at SMP Negeri 3 Surakarta with 31 students in class 9. The data collection instruments used are pre-test and post-test questions and student response questionnaires.

At the implementation stage, the data obtained will be used to determine the level of effectiveness and practicality of the product. The level of effectiveness of the product is known by calculating the student's pre-test and post-test scores. The step of determining the level of effectiveness is done through several tests, which in sequence are the normality test, the homogeneity test, the paired sample t-test, and the n-gain score test. According to Hake, (1999), the n-gain classification is shown in Table 2.

Table 2. Classification of N-Gain Values

No	Values	Classification
1	N-Gain ≥ 0,7	High
2	0,30-0,70	Medium
3	0,00-0,29	Low

Table 3 below shows the criteria and classification to improve student learning outcomes.

Table 3. Criteria for Improving Learning Outcomes on the N-Gain Percentage

N-Gain Percentage	Classification
81%-100%	High
61%-80%	Medium
41%-60%	Moderate
21%-40%	Very Low
10%-20%	No Improvement

In order to interpret the effectiveness of the n-gain score obtained, in Nasir, (2016) can use the criteria shown in Table 4.

Table 4. Classification of N-Gain Effectiveness

Percentage (%)	Interpretation
< 40	Not Effective
40-55	Less Effective
56-75	Moderately Effective
> 76	Effective

The fifth or final stage is an evaluation that will explain all the advantages and disadvantages of AR-based interactive modules on curved space building materials. The flow of research and product development using the ADDIE model is presented in Figure 1.

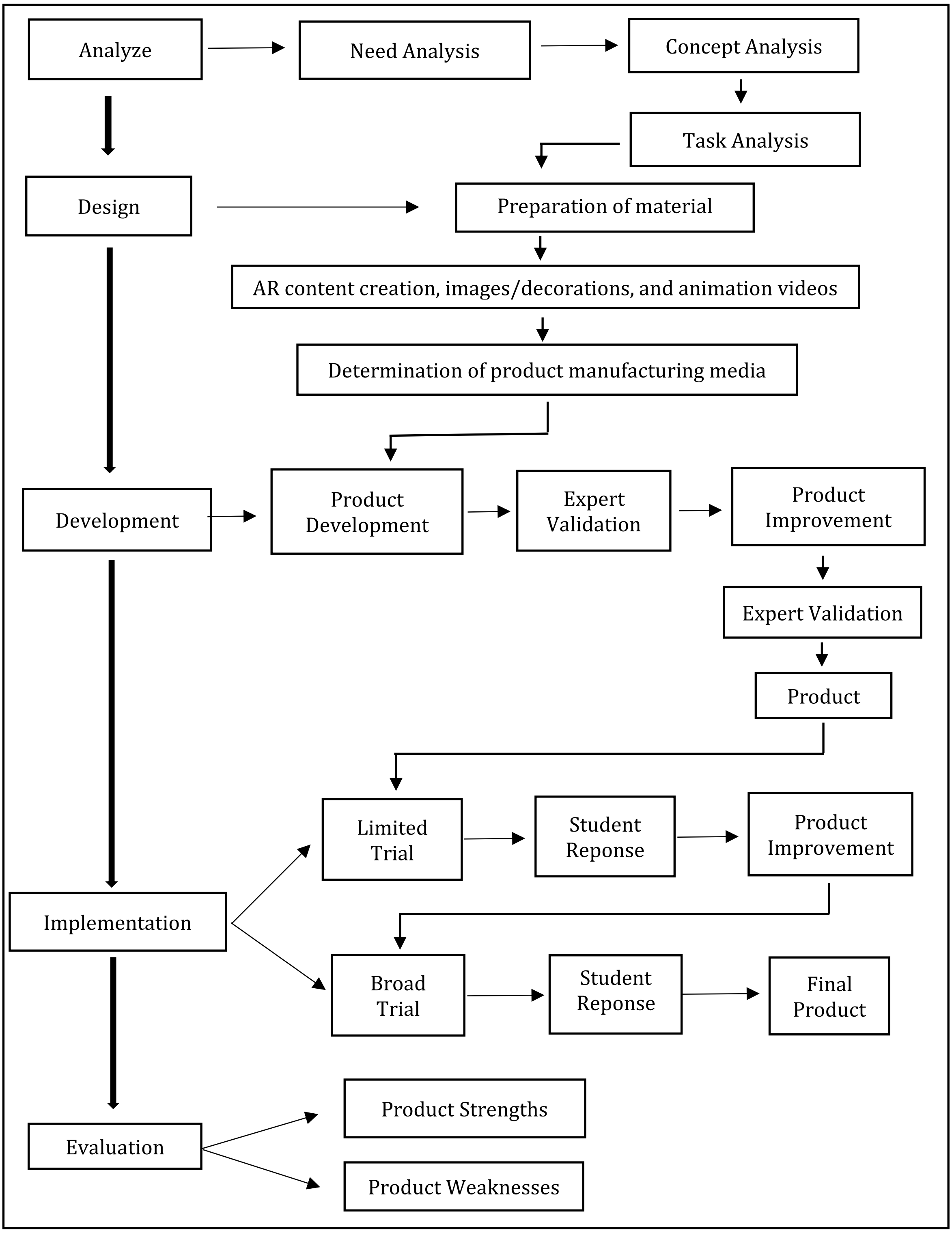


Figure 1. Flow of Research and Development Using the ADDIE Model

The level of practicality is done by calculating the scores obtained through student response questionnaires using SPSS and Microsoft Excel. The scores obtained from the respondents were calculated on average (Mean) and the average percentage of TCR (Respondent Achievement Rate) and then classified using Tables 5 and 6 to determine the level of practicality. The resulting product can be said to be practical if it meets the minimum classification achieved which is the good category.

Table 5. Classification of Mean Product Practicality

Mean Total	Criteria
3,25 < $\bar{x}$ ≤ 4,0	Very Good
2,5 < $\bar{x}$ ≤ 3,25	Good
1,75 < $\bar{x}$ ≤ 2,5	Less
1,0 < $\bar{x}$ ≤ 1,75	Very Poor

In Sugiyono, (2019) the TCR classification of product practicality is presented in Table 6 below.

Table 6. TCR Classification of Product Practicality

Percentage of Achievement	Criteria
85% - 100%	Very Good
66% - 84%	Good
51% - 65%	Moderate
36% 50%	Less Good
0% - 35%	Not Good

RESULTS AND DISCUSSION

The Analysis Stage consists of 3 stages which are requirements analysis, concept analysis, and task analysis. In this needs analysis contains the identification of problems that students have. The result found through observation at SMPN 3 Surakarta is the lack of support needed for students in learning, such as learning media that for students can increase a person's desire to learn. According to what the math teacher said that students are very happy doing learning activities using learning media because according to students learning with media integration becomes easier to understand and increases curiosity about the material being learned. In addition, learning with the implementation of media according to teachers can improve student learning outcomes. According to the teacher's statement, in learning to build a curved side space, learning media such as power point and three-dimensional space props have been used. However, according to the teacher, the use of learning media with a new, interactive, creative, and innovative model is required to be a variety of options for the use of learning media so that students do not get bored and then can be adapted to use which learning media. so that they have the right choice with the material to be discussed.

In the observation in the field, some questions were also presented to the students and they (students) revealed that learning to build a curved side space with the teacher was carried out using three-dimensional props, the students felt that they had no obstacles when learning at school because of the use of these props. However, when students learn the material at home, they (students) find it difficult because they do not have their own props. Based on students' narratives, the use of virtual and real-time teaching aids can help students bridge the constraints of mathematics in the real world and the abstraction of mathematics. Therefore, the product in this study in the form of an Interactive Module Based on Augmented Reality (AR) is expected to be a learning medium that helps students in learning curved sided spaces.

In concept analysis, the material concept in the developed product is determined. The concept analysis refers to the Basic Competence (KD) so that the material content contained in the AR-Based Interactive Module on Curved Side Space Materials does not have a misconception with the KD. From the results of the conceptual analysis of the building materials of the curved side space, the materials that will be discussed in the Augmented Reality-Based Interactive Module are 1) the shape of tubes, cones, and spheres in everyday life; 2) elements of tubes, cones, and spheres; 3) tubular, conical, and spherical nets; 4) surface area of tubes, cones, and spheres; 5) volume of tubes, cones, and spheres.

This task analysis refers to the basic competencies that contain the student task design contained in the product in the form of an AR-based Interactive Module on Curved Side Space. The form of the task contained in the AR interactive module must meet the Competency Achievement Indicators and Learning Objectives of the curved side space building, such as the form of a problem that when students work on the problem, the teacher can capture the extent of the student's abilities. The results of the task analysis generated in the AR-Based Interactive Module on Materials of Curved Lateral Spaces are task requirements for students that contain challenges to recognize the shape of curved lateral spaces, identify the elements and nets of curved lateral spaces, determine the volume and surface area of curved lateral spaces, and solve problems in everyday life related to curved lateral space.

After the analysis stage is completed, the next step is the design stage. The first step in this stage is to prepare the material content. The content in the AR-Based Interactive Module on Curved Lateral Space Building Materials is arranged starting from the introduction, core, conclusion and bibliography. The introduction contains the conclusion, preface, table of contents, basic competencies, competency achievement indicators, learning objectives, and AR usage instructions. The core section contains concept maps, tubes, cones and spheres. The concluding section includes a summary, practice questions and enrichment. The bibliography/reference section containing material/content sources in the curved sidebar contained in this AR-based Interactive Module should come from a reliable and trustworthy source such as a teacher's companion book for grade 9 primary school materials, grade 9 primary school. companion book school students, and 9th grade elementary school textbooks.

The second step is the creation of AR content, animated images and videos. AR (Augmented Reality) content is in the form of markers that can be scanned to display images and videos within. This AR content was created using Assemblr. Furthermore, two-dimensional image content is made in jpg/png format and its creation uses the digital image application that is Medibang. For content in the form of animated videos of curved lateral space meshes created using Geogebra. The third step is to determine the media to make the product. After the material content, AR, images, and animated videos have been created, then perform the processing of the content into the form of an AR-based Interactive Module on the Curved Side Room Building Material. Preparation into module form is done using Canva.

After the design of the product to be developed is completed, the implementation of product manufacturing is carried out in the next stage, which is the development stage. What is done in this stage of development is to create the product and test the level of validity of the product. in making a product there are 4 contents to be made which are to create a curved side space net animation video, to create image content, to create ar content, and to create an interactive module based on the curved side space building material. Animation of a curved space mesh made using Geogebra. Will be displayed on the product in the form of a QR code that when scanned will go to the Youtube site to play a net-net animation of the curved part of the space. The process of creating an animated video net using Geogebra is shown in Figure 2.

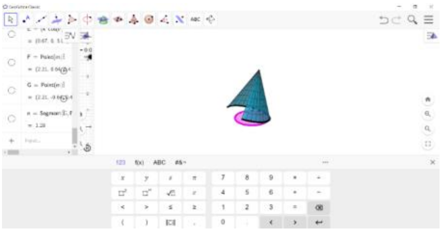


Figure 2. Cone Net Generation with Geogebra

The image content in question is a two-dimensional image of the shape of the curved side space displayed in the product, then the image of decoration/jewelry is used to beautify the design of the product. Other image content creations are product backgrounds, front cover designs, two-dimensional shapes of curved side space nets, cone and blanket tube images, also lidless or baseless images, and real-life examples of curved side space images. Image content is created using Medibang which will be displayed on the product in jpg or png format. The process of making a drawing of an example of a spherical shape in daily life is shown in Figure 3.

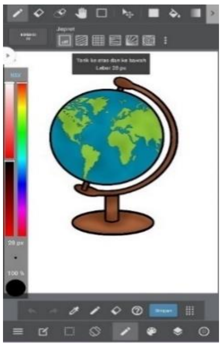


Figure 3. Examples of Real-Life Ball Shape Images

The process of making a product cover using Medibang is shown in Figure 4.

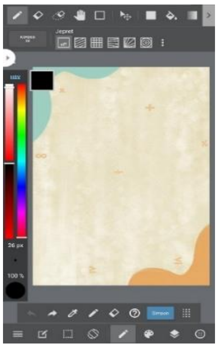


Figure 4. Create a Product Cover Design

Augmented Reality content is created using the Assemblr application. The shape of the curved space in AR mode is displayed in the Marker scanned by the camera. The AR content of this curved side chamber is virtually three-dimensional and real-time displayed interactively. The process of creating AR content using Assemblr is shown in Figure 5.

Figure 5. Cone AR Content Creation with Assemblr

Figure 6 below displays the AR content when scanned with the model placing the AR content where we are.

Figure 6. Display when Marker is Scanned AR Content when Scanned with Model Place it in Room

After the content material in the product is made, then the manufacturing or preparation of the product is carried out, which is an Interactive Module Based on Augmented Reality on the Curved Side Space Building Material. Creating this product using Canva, the product will be in pdf format and can be accessed via a QR code scanned using Google Lens. The process of making AR-based interactive modules on curved space building materials is presented in Figure 7.

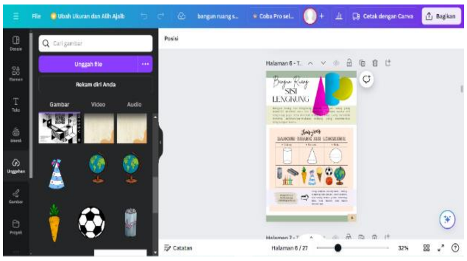


Figure 7. Product creation using Canva

After the product is made, the product validity test will then be conducted to 2 material experts and 2 media experts, whose results are shown in Table 7.

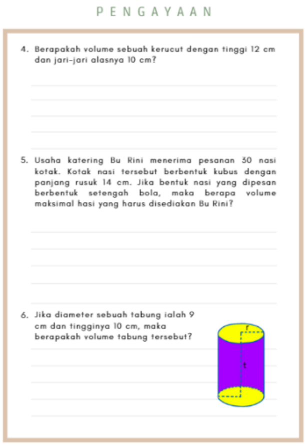
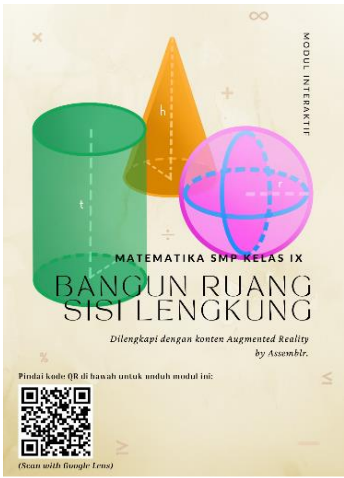
Table 7. Results of Material Expert and Media Expert Assessment of Products

Expert Assessment	Aspect of Material Expert Assessment			Media Expert Assessment		
				Graphic Assessment Aspect		
	Feasibility of Content	Feasibility of Presentation	Language Use	Module Size Design	Content Cover Design	Content Design
Average CVI	0,76	0,92	0,71	1	0,88	0,88
Validity Interpretation	High	Very High	High	Very High	Very High	Very High

The three cvi values in the material expert assessment section shown in Table 7 if calculated on average will result in a value of 0.79 which based on Table 1 is included in the "high validity" category. Furthermore, for the evaluation of media experts shown in Table 7, if the three cvi values are calculated on average, it will produce a value of 0.92 which is included in the "very high validity" category based on Table 1. Material experts and media experts also give criticism and suggestions used to improve the product. a list of product improvements is presented in Table 8.

After the product in the form of an AR-based interactive module on the building material of curved lateral space has met the feasibility through validity testing by experts, it will be tested in learning. Here are some displays of the products developed in this study. Figure 8 is a display of tube materials in an AR-based interactive module.

Table 8. List of Product Improvements Based on Material Expert Assessment

<table>
<tr><th colspan="2">Comments and Suggestions</th><th>Product Display Before Improvement</th><th>Product Display After Improvement</th></tr>
<tr><td>From Material Expert</td><td>Added practice questions as enrichment for student independent practice.</td><td></td><td></td></tr>
<tr><td></td><td>Error writing order on page 16</td><td></td><td></td></tr>
<tr><td>From Media Expert</td><td>The color pattern on the cover of the building material module of the curved side space can be combined more attractively and adapted to the color elements that are suitable for elementary school students' learning material books and pay attention to the psychology of color.</td><td></td><td></td></tr>
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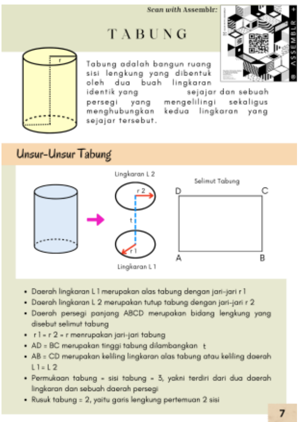

Figure 8. AR-based Tube Material Display

Cone material display in an AR-based interactive module is shown in Figure 9.

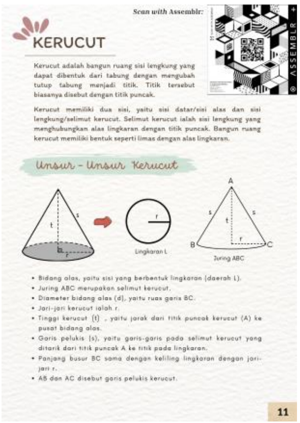

Figure 9. AR-based Cone Material Display

The display of the spherical material in the AR-based interactive module is shown in Figure 10.

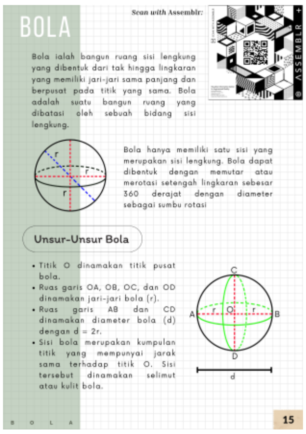

Figure 10. AR-based Sphere Material Display

The material part of the tube net in the AR-based interactive module is shown in Figure 11.

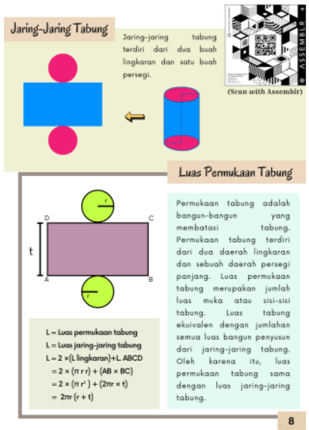

Figure 11. AR-based Tube Net Material Display

In the AR-based interactive module, there is a cone net material displayed in Figure 12.

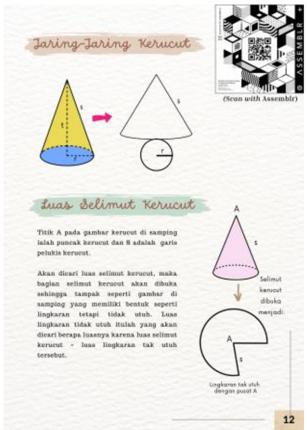

Figure 12. AR-based Cone Net Material Display

The conclusion part of the curved side space building material in the AR-based interactive module is shown in Figure 13.

Figure 13. AR-based Material Summary Display

Implementation is carried out after the product gets a high validity assessment and is declared usable for research by experts. The implementation of the product is carried out in 2 trials, namely a limited trial and an extensive trial. A limited experiment was conducted on 9 students and an extensive experiment was conducted on 24 students. In this implementation stage, the results obtained through trials are used to see the effectiveness of the product. At this stage of implementation, the level of product effectiveness will be known through the calculation of pre-test and post-test student score data obtained in limited trials and extensive trials. The test results to determine the level of effectiveness are shown in Table 9.

Table 9. Product Effectiveness Test Result

Test Type	Significance Value of Shapiro-Wilk Normality Test		Significance Value of Bartlett Homogeneity Test	Paired Sample t-Test Test		Average Test Score		Average N-Gain Score	*N-Gain* (%)
	Pre-Test	Post-Test		t_{count}	Sig. (2-tailed)	Pre-Test	Post-Test		
Limited Trial	0,301	0,158	0,288	7,85	0,000	20,14	70,71	0,63	63%
Broad Trial	0,071	0,244	0,683	11,091		26,58	70,79	0,62	62%
Interpretation								Moderately Effective	

The significance value in the paired sample t-test presented in table 9 is 0.000. A significance value of less than 0.05 means that H_1 is accepted. For the restricted trial, the t_{table} value is 1,943 and the t_{test} is 7,85. Then for the wide experiment the value of t_{table} is 1,714 and t_{test} is 11,091. In limited trial and wide trial have $t_{test} > t_{table}$ which means H_0 is rejected. So, there is a significant difference in the pre-test and post-test scores of students in learning by applying the Augmented Reality-Based Interactive Module on Curved Side Space Materials.

Table 9 shows the average value of n-gain obtained in a limited trial of 0.63 with a percentage value of 63% and in a wide trial of 0.62 with a percentage value of 62%. Based on this percentage value, the effectiveness level of the product refers to Table 4, the result is that the AR-based interactive module is "moderately effective" in learning curved sided space building.

At this stage of implementation, the level of practicality of the product will also be known through the calculation of data on the student response questionnaire. The product practicality test was conducted on 28 students who filled out the student response questionnaire and the results are in Table 10.

Table 10. Product Practicality Test Result

Aspect	N	Score	*Mean*	TCR	Criteria *Mean*	Criteria TCR
Cognitive		93,29	3,33	83%	Very Good	Very Good
Affective	28	91,42	3,26	82%	Very Good	Good
Conative		86,14	3,08	77%	Good	Good
Average		90,28	3,22	81%	Good	Good

Based on Table 10, the average score of respondents on the student response questionnaire is 3.22. This value when referring to Table 5 is included in the "good" criteria. Furthermore, the TCR percentage is 81%, when referring to Table 6, it is classified as "good".

After the product has been applied in learning and calculations have been made on the data obtained from limited trials and extensive trials, the final stage is the evaluation stage. During the evaluation stage, the product is evaluated from the initial development step to implementation. Products developed, validated by experts and implemented in learning, must be evaluated. Evaluation is carried out by checking whether the revisions made are in accordance with the recommendations of experts. The evaluation also included checking the results of the implementation stage, which found that the product was still included in the moderately effective classification when used in learning about curved Sided space buildings. Therefore, consideration is given to further product development. In addition, product strengths and weaknesses are identified. One of the disadvantages of the product is that the scanning of AR content can only be done by users with internet access. Nevertheless, there is certainly an advantage or innovation in the product developed in this research compared to previous studies, which is the use of AR visualization to help students understand the geometric shape of curved surfaces in training questions.

CONCLUSIONS AND SUGGESTIONS

Based on the findings of data analysis from research and development (R&D) carried out by researchers, it can be concluded that the development of Interactive Modules Based on Augmented Reality on Building Materials with Curved Side Spaces using the ADDIE model has been confirmed through product testing according to materials. experts, resulting in an average CVI of 0.79, categorized as "high validity". Furthermore, from media experts, an average CVI of 0.92 was obtained, classified as "very high validity". In terms of product effectiveness, in a limited trial, an average n-gain percentage of 63% was achieved, and in a wider trial, 62%, classified as "moderately effective". Furthermore, for the practical test based on student response questionnaire data, an average mean score of 3.22 and an average TCR percentage of 81% were obtained, both within the "good" criteria. Therefore, the product developed in this study can be considered valid, practical, and effective enough to be used in education.

The development of AR-based spatial geometry learning media with superior models compared to previous studies is expected to be the subject of future studies. In addition, the development of media to facilitate learning in other subjects by integrating compatible technology to create more effective and efficient teaching and learning activities should also continue.

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