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Development of Manipulative Media "Brusil Board" for Curved Side Space

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Abstract: Curved-sided space is a math material taught at the junior high school level. This material is considered difficult for students because there are so many formulas that must be understood as well as memorized. Therefore, learning media is needed that can help the above problems. This research aims to produce a valid and practical Brusil Board manipulative media used by teachers and students in learning activities for the volume of curved-sided space. The type of research used is Research and Development with the ADIIE model which consists of 5 stages including analysis, design, development, implementation, and evaluation stage. The test subjects consisted of ten students of the master of mathematics education. The research instruments used include validation sheets and student response questionnaires. The results show that the total average percentage of the validation test was 84.25% from the experts and the total average percentage of the practicality test was 90% from the test subjects. So, it can be concluded that the Brusil Board manipulative media is declared very valid and practical to be used by teachers and students in learning so that the concept of volume of curved-sided space can be well constructed in students' knowledge.

Keywords: Brusil board, Curved sided space, Manipulative media

Introduction

Curved-sided space is a mathematical material in the geometry family that is taught at the junior high school level. The objects in this material are very close to students and are often encountered in everyday life. The basic competencies of curved-sided space topic itself consist of finding the surface area and volume of tube, cone, sphere and their combinations and solving contextual problems related to the material (Kemendikbud: 2017). However, several studies have revealed that there are still many student problems in the field related to curved-sided space topic, including the results of Agustini & Fitriani's research (2021) and Arifin et al. (2017) show that students still have difficulty learning curved-side space topic because they have not fully mastered the concept of curved-sided space, then the results of research by Marasabessy et al. (2021) also shows that students still make mistakes in solving curved-sided space problems which are generally motivated by not mastering the concepts and principles. This shows that the five senses of students still find it difficult to observe the abstractness and usefulness of mathematics (Marasabessy et al., 2021).

As an effort to overcome the above problems, a teacher needs to develop media as a bridge to connect students' concrete level of thinking to a more abstract level of thinking. Learning media is believed to make it easier for students to learn abstract math concepts (Purnama et al., 2017). According to Perbowo et al. (2019), learning media is one of the solutions to overcome difficulties in learning mathematics. More detailed Isnaniah & Imamuddin (2020) explained that learning media can provide an early introduction to mathematical concepts for students according to their cognitive development stages. The material of curved-sided space has a formula that is difficult to understand if it is only limited to memorization by students, so media is still needed so that the concept of curved side space can be understood easily. This is in line with the opinion of Rohaeti et al. (2019)

which suggests that learning media is a tool that can convey mathematical concepts to students in a real form so that students can understand these concepts not just memorize. Latifa et al. (2022) also added that the use of mathematics learning media aims to design teaching and learning activities so that they take place effectively and fun.

The more interesting the learning media, the more it attracts attention and stimulates students in teaching and learning activities (Nugraheni, 2017). One of the learning media that can attract students' attention is manipulative media (Isnaniah & Imamuddin, 2020). Manipulative media is defined by Muhsetyo in Isnaniah & Imamuddin (2020) as media that can be seen, touched, heard, and manipulated. Meanwhile, according to Astutik & Qohar (2021) manipulative learning media is a very valuable tool in teaching mathematics. Manipulative learning media has very broad benefits, including learning activities will be more interesting so as to increase learning motivation, learning will be more varied, learning takes place not only listening to lectures from the teacher but students are given the opportunity to observe, do, and demonstrate manipulative media tools so that students are not easily bored and the teacher does not spend a lot of energy. Several studies have also shown that students' mathematics learning outcomes using manipulative learning media can improve significantly (Irfan & Sulistyaningrum, 2019; Tumangkeng et al., 2021; Yulia et al., 2021).

In this study, the manipulative media that will be developed by researchers is the Brusil Board media which is only limited to the topic of determining the volume of curved-sided space. The word “Brusil” stands for curved-sided space. The Brusil Board manipulative media consists of a tube, cone, and sphere that has the same size base diameter and height and then glued to the board. This Brusil Board media explains the origin (proof) of the volume formula of curved-side space by linking the volume of tube, cone and sphere. This is in line with the statement made by NCTM (National Council Teacher of Mathematics) that mathematics is a discipline that is rich in concepts. Where these concepts have a high relationship, that is, one concept can support another concept (NCTM, 2000). Thus, it is expected that the Brusil Board learning media helps students construct their knowledge regarding the volume of curved-sided space without having to memorize formulas.

Based on the description above, the researcher considers that this development research needs to be done. This research aims to produce Brusil Board learning media on curved-side space material that is valid and practical to be used by teachers and students in mathematics learning activities so that the concept of curved-sided space, especially on the topic of determining volume, can be well constructed in students' knowledge.

Method

Based on the research focus, this research is a development research, namely the development of Brusil board manipulative media applied to curved-side spaces topic. This research uses the ADDIE development model which consists of 5 stages, namely (1) Analysis, (2) Design, (3) Development, (4) Implementation, and (5) Evaluation (Branch, 2009). According to Nieveen (1997) in Hobri (2009), to determine the quality of learning media developed, it is necessary to conduct testing, namely validity, practicality, and effectiveness tests. However, the effectiveness test was not used because in this study the subjects were master of mathematics education students. The validity test was carried out to find out whether the product that the researcher had produced was in accordance with the manipulative media development pakem during the math learning process or not. The practicality test was carried out to see the usefulness of the manipulative media produced in the learning process, whether it is easy to use, attracts students' interest, and is fun or needs revision.

The research instrument used to test the validity of the product is in the form of a manipulative media validation sheet which is assessed by one mathematics education lecturer with the title of Professor and two observers of master of mathematics education students. While the research instrument used to test the practicality of the product is in the form of a student response questionnaire sheet filled in by the test subjects, namely ten students of the master of mathematics education at Malang State University.

Table 1. Media validity/practicality result criteria

Percentage	**Criteria**	**Information**
76%-100 %	Very valid/ practical	No needed revision
51%-75%	Valid/ practical	No needed revision
26%-50%	Less valid/ less practical	Need revision etc
0%-25%	Invalid / no practical	Need total revision

(Modification from Purnawati & Qohar, 2022) .

The data analysis technique for the results of the validity and practicality tests was carried out according to the analysis technique (Hobri, 2010), namely: 1) summarize the data from the product assessment results into a table containing aspects, indicators, and values for each validator, 2) determine the average of the assessment results from each validator for all indicators, and 3) determine the percentage of validity or percentage of practicality, which is the total average result of the average value for all dimensions/aspects. Then, the results obtained will be adjusted to the criteria for validity/practicality of manipulative media as in Table 1 above. Meanwhile, to calculate the total percentage of average value of the assessment result for all indicators using the formula:

$$P = \frac{\text{total average obtained}}{\text{total maximum average}} \times 100\%$$

Results and Discussion

Results

Analysis Stage

The first stage of this development research is the analysis stage, which analyzes the main problems in the mathematics learning process. This analysis stage includes two phases, namely performance analysis and needs analysis (Branch, 2009). Performance analysis is conducted to identify and clarify the problems that require improvement in learning activities. The needs analysis includes steps to identify the competencies that students want to achieve (Branch, 2009; Sari & Qohar, 2023). In the performance analysis, problems were found in the learning of curved-sided spaces, it shows that there are still many students who do not fully understand the concept of volume of curved-sided space, so students tend to only memorize, even though the ability to remember is the lowest ability in Bloom's taxonomy (Boeren & Íñiguez-Berrozpe, 2022). Meanwhile, the needs analysis shows that the learning media that can be used in the learning process of the volume of curved-sided spaces is still limited. Therefore, researchers conducted the development of Brusil Board manipulative media on curved-sided space material. The competency that students want to achieve is to have the ability to understand the concept of volume of curved-sided space.

Design Stage

The design stage in this study includes activities to design the specifications of the developed media and design instructions for using the developed manipulative media. In this study, the activities of designing media specifications developed included determining the size of the diameter and height of the curved-sided space, sketching, and designing the appearance of manipulative media that is interesting and close to students' lives. Meanwhile, instructions for using manipulative media are presented in the form of learner worksheets (LKPD) so that the activities carried out by researchers are preparing materials and designing attractive displays of learner worksheets (LKPD).

Development Stage

Brusil Board manipulative media consists of several components, namely magnetic whiteboard, tube and cone made of paddy cardboard, sphere that split two equal parts, styrofoam particles used to fill the volume of curved-side space, and instructions for use (LKPD). Table 2 below presents the tools and materials used to make the Brusil Board media.

Table 2. Tools and materials for making brusil board media

No	Tool	Material
1	Scissors	Magnetic Whiteboard
2	Ruler	Paddy cardboard
3	*Cutter*	Plastic sphere
4	Korean Glue/G	styrofoam particles of the same size
5	Wood glue	Magnets
7		Tin foil

The method of making Brusil Board manipulative media is as follows: The first step is to draw patterns of tube and cone without covers on a paddy cardboard. The tube and cone patterns are drawn with the help of a ruler and a period. The tube and cone to be made have a base diameter of 14 cm and a height of 14 cm. The second step is to cut following the pattern that has been formed using scissors. Next, glue the pieces of the pattern into the desired tube and cone. To make it look more attractive, the next step is to coat the tube and cone with tin foil. The third step is to split a sphere with a diameter of 14 cm and a height of 14 cm into two equal parts using a cutter. The product is presented in Figure 2 below.

Figure 1. Tube, cone, and sphere that split into two equal parts

The fourth step is to prepare styrofoam particles of the same size to fill the volume of tube, cone, and sphere. The styrofoam particles is presented in figure 2 below.

Figure 2. Styrofoam particles

The last step is to attach the tube, and both hemispheres of the sphere to the magnetic board using glue. While the cone is attached using a magnet (so that it can be lifted and moved). The developed Brusil Board manipulative media can be seen in Figure 3 below.

Figure 3. Brusil board manipulative media

The instructions for using the Brusil Board manipulative media are provided in the learner worksheets (LKPD) approximately as in Figure 4 below.

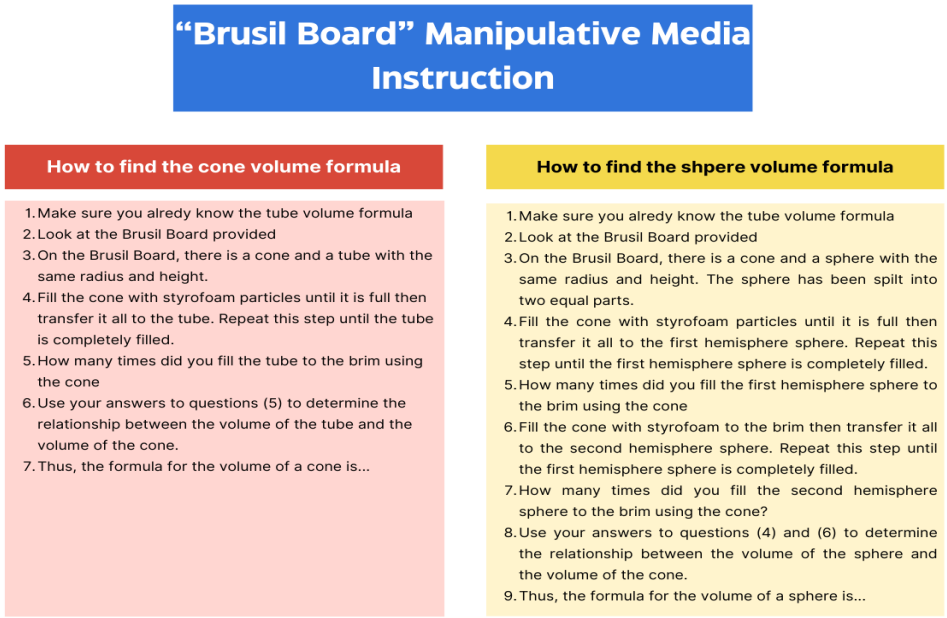

Figure 4. Brusil board manipulative media instruction

Implementation Stage

The implementation stage is the stage where researchers conduct media validation tests and practicality tests. The media validation test was carried out by one mathematics education lecturer with a professor title and two master of mathematics education student observers, while the media practicality test respondents consisted of ten master of mathematics education students at Malang State University. The results of the media validation test by experts are shown in Table 3 below.

Table 3. Media validity test results

Aspect	Average
Contents of Learning Media	
Learning media can help students learn to determine the volume of curved-sided spaces	3.6
Learning Media can help students build an understanding of concepts of the volume of curved-sided spaces	3.6
The activities provided allow for positive interaction between students and the learning media	3.3
The activities contained in the use of appropriate learning media with objective learning.	3
Learning media is not ambiguous	3.3
Uses of Learning Media	
Can be used to help assist students in achieving learning objectives	3.6
Can be used as a support for learning the volume of curved-sided spaces at school	3.3
Can encourage students to be more active in learning	3.6
Can create an interesting learning atmosphere so that students are not bored	3.6
Shape and Appearance	
The appearance of the learning media is interesting	3.6
Proportional media shape	3
The developed learning media is not easily damaged	3
Average	3.37
Percentage	84.25%
Category	Very Valid

The Table 3 above shows the results of the media validation test by experts. Based on the data obtained by researchers, the Brusil Board manipulative media obtained an average score for each indicator categorized as valid and the total average percentage for all indicators was 84.25%, which means that based on Table 2, the Brusil Board media is very valid to be used by teachers and students as a learning media for curved-sided space and no revisions are needed. While the results of the media practicality test by the test subjects are shown in Table 4 below.

Table 4. Media practicality test results

Indicator	**Average**
Brusil Board media is easy for me to use	3.6
Brusil Board media helps me understand the concept of volume of curved-sided spaces	3.8
I enjoy learning math through this learning media	3,4
This learning media makes me like math	3.3
This learning media makes me actively learn math	3.7
This learning media makes me not bored learning math	3.7
This learning media makes me want to understand more about math	3.5
Instructions and information presented easy for me to understand	3.7
The appearance of the Brusil Board manipulative media is interesting	3.8
The Brusil Board media display is close to the student's environment	3.5
Average	3.6
Percentage	90%
Category	Very practical

The Table 4 above shows the results of the media practicality test by the test subjects Based on the data obtained by researchers, the Brusil Board manipulative media obtained an average score for each indicator categorized as practice and the total average percentage for all indicators was 90%, which means that based on Table 3, the Brusil Board media is declared very practical to be used by teachers and students as a learning media for curved-sided space and no revisions are needed.

Evaluation Stage

The evaluation stage of the Brusil Board learning media is carried out according to the results of validation test and practically test. Based on the results of validation sheets and student response questionnaires, researchers made improvements to the media including printing LKPD with a larger size and replacing the styrofoam particles filled into tube, cone, and sphere into styrofoam particles that have the same size.

Discussion

The use of manipulative media in mathematics learning has become commonplace in the world, including Indonesia. Research in general also shows that learning that uses manipulative media has better results than learning that does not use (Simon, 2022). Students who gain understanding through manipulative media tend to be able to connect their real world and abstract mathematics (Fossa, 2004). In other words, students will find it easier to learn and understand math when the learning process looks real to them. In essence, the teacher's role is only to stimulate student activeness through the provision of learning activities supported by manipulative media, while students process and understand the material themselves according to their desires, abilities, talents, and backgrounds (Atsara & Qohar, 2022).

The Brusil Board manipulative media that has been developed by researchers aims to help students understand concepts and invite students to be more active in learning, especially in the material of the volume of curved-sided space. This is in accordance with several studies which reveal that the application of manipulative media in mathematics learning can increase student learning activities (Afifah & Kristin, 2023; Isnaniah & Imamuddin, 2020; Latifa et al., 2022; Wulandari & Qohar, 2022). Based on the development results, the validity test of the Brusil Board media obtained a total average percentage of 84.25% for all aspects and the practicality test of the Brusil board media obtained a total average percentage of 90% for all indicators. This shows that the Brusil Board media is declared very valid and very practical to be used in learning mathematics without any revisions.

More specifically, in terms of content and usability, the Brusil Board media obtained an average total score of 3.36 and 3.5, which means that the content and usability are in accordance with the learning media development pakem. Meanwhile, from the aspect of the shape and appearance of the Brusil Board media, it obtained an average total score of 3.2, which means that the shape and appearance are also in accordance with the learning media development standard. But on the other hand, there are still some suggestions from researchers when teachers plan to develop and use Brusil Board media, including: 1) Choosing sturdier materials to make curved-side space so that the shape is more precise and appropriate, 2) Choosing smaller and more precise materials to fill the volume of the curved side space. This activity of modifying manipulative media is very necessary to do to produce media that can be applied properly in accordance with its development objectives.

Through the application of the Brusil Board manipulative media, the researcher directs students to learn the concept of volume of curved-sided space. In groups, students are asked to demonstrate the media in front of the class, so that they can gain direct learning experience and discover the concept of volume of curved-sided space independently, thus indicating the creation of meaningful learning. This is in line with Simon's (2022) statement that manipulative media can create meaningful learning. Zippert et al., (2019) explained that concrete activities with the use of manipulative media are valuable learning for students. Students in groups with their peers use media and worksheets that are very important for students' mathematical exploration. The statement of Zippert et al. (2019) above is supported by the results of systematic literature research conducted by Palupi (2020) which shows that of the 20 research articles that discuss the use of manipulative media, reveal that manipulative media can stimulate students' understanding of concepts, increase student and teacher activities, and find happy student responses during the learning process.

Conclusion

Based on the results and discussion above, it can be concluded that the development of Brusil Board manipulative media on curved-side spaces topic is declared very valid and very practical to be used in learning curved-sided space topic with the acquisition of a total average percentage of 84.25% validation test from experts and a total average percentage of 90% practicality test from test subjects.

Recommendations

Based on the research analysis, further research is still needed to determine the effectiveness of the Brusil Board manipulative media development on curved-sided space topic.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

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