UJME 11 (3) 2022: 228-238
UNNES JOURNAL OF MATHEMATICS EDUCATION
https://journal.unnes.ac.id/sju/index.php/ujme/
ISSN: 2252-6927 (print); 2460-5840 (online)

Development of Teaching Materials of Flat Side Spaces Building Based on Problem Based Learning with Assemblr Assistance to Improve Students' Spatial Ability

Siti Lailiyatul Maqfiroh[a,*], Detalia Noriza Munahefi[a]

[a] *Mathematics Department, Universitas Negeri Semarang, Sekaran Campus,Gunungpati, Semarang, 50229, Indonesia*

* *E-mail address: sitilailiyatulmaqfiroh@students.unnes.ac.id*

ARTICLE INFO

Article history:
Received 20 September 2022
Received in revised form 25 September 2022
Accepted 18 October 2022

Keywords:
Development of Teaching Materials; Problem-Based Learning; Spatial Ability

Abstract

This study aims to develop teaching materials for flat-side space buildings based on problem-based learning assisted by Assemblr to improve students' spatial abilities. The method used was Research and Development with a 4D development model modified to 3D, namely: define, design, and develop. The last stage (dissemination) was not carried out due to the limitations of energy, cost, time, and deployment space of the researcher. The data collection technique used a questionnaire, which consists of a feasibility test and a readability test. The results of the feasibility test obtained a percentage of 89% meaning that teaching materials were declared suitable for use in learning. The readability test results obtained a percentage of 87% meaning that the teaching materials were declared easy for students to understand. The results of the study obtained teaching materials that are valid and suitable for use in learning and are easy to understand by readers.

1. Introduction

The curriculum in Indonesia requires students to understand geometry material from elementary school to college. Geometry is also part of the mathematical content standards set by NCTM. The five content standards in the mathematical standards set by NCTM (2000) are numbers and their operations, problem-solving, geometry, measurements, and opportunities and data analysis. According to Arifin et al. (2020) when studying geometry, especially concerning the three dimensions, a student must be able to understand the shape of a space construct even though they do not see it directly, students must be able to construct a wake in their mind. Sudirman & Alghadari (2020) added that modeling, spatial reasoning, and the use of visualization are elements contained in geometry. This shows that spatial ability is a curriculum demand that needs to be facilitated and fulfilled in learning.

Lestari and Yudhanegara (2015) define spatial ability as an ability to determine, guess, imagine, compare and obtain information from visual stimuli in the context of space. Spatial ability indicators consist of: (1) spatial orientation, (2) environmental ability, (3) flexibility of closure, (4) spatial relations, (5) spatial visualization, (6) spatiomeporal ability, (7) perceptual speed, and (8) closure speed (Yilmaz, 2009). The mathematical spatial ability makes it easier for students to understand the geometry of space and helps them in obtaining material so that students' learning desires will be encouraged, not only accepting concepts, but they can also imagine and explain in detail abstract geometry so that it appears clearer.

Spatial ability is a really important thing for students to have, but some previous research results have shown that students' spatial abilities are still weak. One of these studies is the research of Sutadnyana (2013) which revealed that most students find it difficult to solve mathematical problems, especially problems related to the three dimensions that require spatial ability, so the results obtained are very unsatisfactory. This is due to the large number of geometric problems that require visualization when solving problems

To cite this article:
Maqfiroh, S. L. & Munahefi, D. N. (2022). Development of Teaching Materials of Flat Side Spaces Building Based on Problem Based Learning with Assemblr Assistance to Improve Students' Spatial Ability. *Unnes Journal of Mathematics Education*, *11*(3), 228-238. doi: 10.15294/ujme.v11i3.60568

and most students feel difficulty in constructing geometric shapes (Kariadinata, 2010). Adam and Zulkarnaen (2019) added that the low spatial ability of students is because students are only able to imagine image objects to determine patterns, while in solving problems and conceptualizing answers to geometry problems, they are still unable to. Based on the results of the study, it can be said that students' spatial abilities are still low, so efforts are needed to improve students' spatial abilities.

Previous research revealed that spatial abilities can be improved using Problem Based Learning and the use of augmented reality in learning. Problem Based Learning can be used for two purposes, namely to instill concepts and to develop certain abilities such as spatial abilities through the problems presented. The problems used in Problem Based Learning are generally related to real life. Many objects in the real world are related to flat-side space buildings so that they can be used as various forms of questions/problems. The problem should be adjusted to the indicators of spatial ability. Research conducted by Wijayanto et al. (2020) stated that the spatial ability of class X students of SMA Negeri 7 Padang City in geography learning using Problem Based Learning increased from 44.11 to 70.16. The results of research by Sugiarni et al. (2018) stated that the use of the Geogebra-assisted Problem Based Learning model can also improve the spatial ability of class XI students at MA Al-Hanif Cibeber on geometry material. Meanwhile, research by Pranawestu et al. (2012) revealed that: (1) the spatial ability of students who use Problem Based Learning with the help of character-based Cabri 3D is stated to be better when compared to the spatial ability of students who use expository learning and (2) student activities have a positive effect on students' spatial abilities in Problem Based Learning with the help of Character-based 3D Cabri on three-dimensional material. Based on this explanation, sit can be said that Problem Based Learning can improve students' spatial abilities.

The use of media in the form of Geogebra and Cabri 3D in the study helps visualize 3D objects needed in geometry learning and can help develop students' spatial abilities. In addition to Geogebra and Cabri 3D, augmented reality can also help visualize 3D objects with a more attractive appearance because they can be displayed in the real world simultaneously. This is following Mustaqim's (2016) statement that augmented reality is a technology that can be used to project 2D or 3D-shaped objects into a real environment simultaneously. Roedavan (2014) also defines augmented reality as a technology that can unite virtual objects in two-dimensional or three-dimensional form into the actual environment and then project the virtual objects in real time.

Augmented reality not only has a more attractive appearance but can also improve the spatial ability of shiva. Research by Arifin et al. (2020) revealed that learning media using augmented reality was declared effective for improving students' spatial abilities. Research by Yanuarto & Iqbal (2022) also revealed that the spatial ability of students of SMP 2 Pamarican increased after using augmented reality learning media. Setiawan and Dani (2021) added that augmented reality technology used as a learning medium has many advantages, including: (1) it is easy to operate, (2) its use is more effective, (3) it can be widely applied in a variety of media, (4) simple object modeling, (5) low budget and (6) more interactive. One application that provides augmented reality features is Assemblr. This is following the statement of Ryza (2017), Assemblr is an android application equipped with augmented reality features to help users create 2D and 3D objects and then project them in augmented reality.

The use of Problem Based Learning and augmented reality in learning will not run optimally without teaching materials. This is in line with the statement of Marika et al. (2020) that learning without teaching materials will take place less optimally, including in mathematics learning. Teaching materials according to Suwartaya et al. (2020) are materials or subject matter that are arranged systematically that are used by teachers and students in the learning process. One of the functions of teaching material is as a guide for both teachers and students who will guide all activities in the learning and learning process (Aisyah et al., 2020). The role of teaching materials for teachers and students according to Suwartaya et al. (2020) namely (1) making the learning process more effective, (2) can save teachers time in teaching, (3) shifting the role of a teacher as the main source of information to become a facilitator, (4) allowing students to learn without the presence of teachers or other students, (5) allowing students to learn anytime and anywhere, (6) allows students to learn at their own pace, (7) allows students to learn in their order and (8) increases students' potential to become independent learners.

The researcher concluded that spatial abilities are important to improve. Efforts to improve spatial abilities can be done by using Problem Based Learning and augmented reality media such as Assemblr in learning. Learning will run optimally if there are teaching materials. The purpose of this study based on this background is to develop teaching materials for flat-sided space buildings to improve students' spatial abilities.

2. Methods,

The research conducted was classified as Research and Development (R&D) to produce a product and then test its effectiveness (Sugiyono, 2016). The product developed in this study was in the form of Problem Based Learning-based teaching materials assisted by Assemblr. In research and development methods there was a wide variety of models to choose from. The model used by the researcher is the development of a 4D (Four D) model. The model was developed by S. Thiagarajan, Dorothy S. Semmel, and Melvyn I. Semmel (1974). The four main stages in the 4D development model consist of define, design, develop and disseminate.

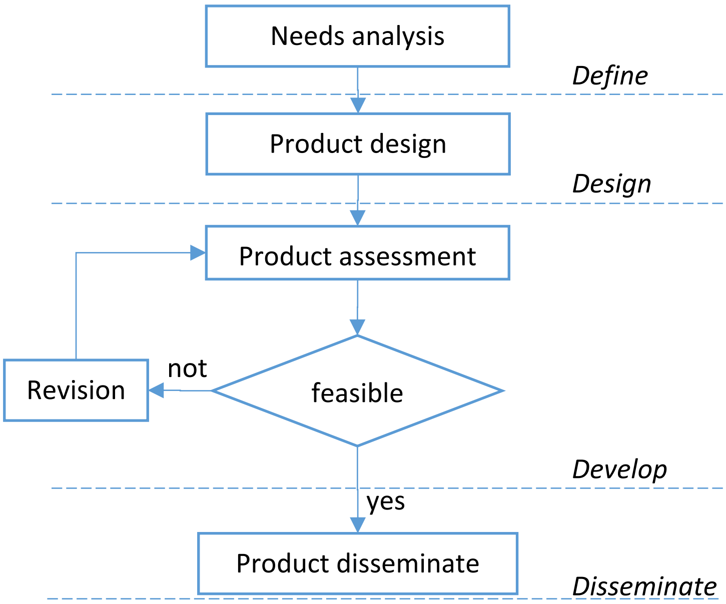


Figure 1. 4D research and development flow

The 4D development model in this study was modified into three stages only, only until the development stage which included expert validation tests and readability tests for teaching materials. In the dissemination stage, the latter stage is not carried out due to the limitations of energy, cost, time, and space of deployment of the researcher. In this study, the defined stage or needs analysis was carried out to determine the problems that occurred in the mathematics learning process and determine the solution. The defined stage consists of final initial analysis activities, student analysis, and task analysis. Task analysis includes the analysis of the structure of the content, the analysis of concepts, procedural analysis, and the formulation of goals. At this stage, researchers obtained the fact that students' spatial abilities are still low, but can be improved by using Problem Based Learning and augmented reality in learning so researchers set up product development in the form of Problem Based Learning-based teaching materials assisted by augmented reality. The design stage contains activities to design products that have been set at the define stage. The design stage consists of collecting references, selecting media, and making teaching material designs. After the teaching materials are completed, enter the stage of development which contains teaching material assessment activities consisting of feasibility tests and readability tests.

The data collection technique in this study used questionnaires, including feasibility test questionnaires and teaching material readability test questionnaires. The feasibility test questionnaire for teaching materials is used to determine or assess whether the teaching materials developed are suitable for use in learning or still have to be improved. The feasibility test questionnaire was given to three mathematics lecturers and one mathematics teacher. The aspects assessed in the feasibility test consist of the feasibility of the content, the feasibility of presentation, and language. Assessment indicators on the aspects of content feasibility include (1) conformity of the material with basic competencies, indicators of competency achievement, and learning objectives, (2) accuracy of the material, (3) supporting the learning material, and (4) updating the material. Indicators of the feasibility aspects of presentation include (1) Presentation Techniques, (2) Presentation support, (3) learning presentation, and (4) completeness of presentation. Assessment indicators on linguistic aspects include (1) straightforward (simple and not convoluted), (2) commutative, (3) dialogical and interactive, (4) conformity with the level of student development, (5) regularity and integration of thought flows, and (6) the use of icons, symbols, or terms. The readability questionnaire of teaching materials is used to assess whether the teaching materials developed can be easily understood by students. The readability test questionnaire for teaching materials was given to three class VIII students. The questionnaires in both tests used the Likert 4 scale to measure the validity and readability of teaching materials with the following details: a score of 1 for very less, a score of 2 for less, a score of 3 for good, and a score of 4 for excellent (Kusumam et al., 2016). The score is then converted to a percentage form using the formula:

$$P = \frac{The\ number\ of\ scores\ obtained}{criteria\ score} \times 100\%$$

Where P is the percentage of eligibility and the criteria score (ideal score) is obtained from the number of items multiplied by the maximum score. Giving meaning and decision-making at the level of validity of teaching materials using the conversion of the scale of achievement levels according to Riduan (2013) contained in Table 1 below.

Table 1. Qualification of the level of validity of teaching materials.

Achievement level	Validity criteria	Information
$80\% < P \leq 100\%$	Very feasible/very valid	Does not require revision
$60\% < P \leq 80\%$	Feasible/valid	Does not require revision
$40\% < P \leq 60\%$	Feasible enough/valid enough	Needs revision
$20\% < P \leq 40\%$	Less feasible /less valid	Needs revision
$0\% < P \leq 20\%$	Not feasible/invalid	Needs revision

The qualification of the level of readability of teaching materials according to Rankin and Culhane (1996) is divided into three, that is, if the readability score:

1) less than 40% means that teaching materials are difficult to understand. Such teaching materials are considered unsuitable for readers;
2) 41%-60% means that teaching materials are at the instructional level. The teaching materials are suitable for readers, but they need help from other parties to assist readers in their understanding, and
3) more than 60% means that the teaching materials are at an independent/free level. The teaching materials are easy to understand and readers can use them independently.

The classification of the level of readability of the teaching materials can be summarized in Table 2.

Table 2. Qualification of the level of readability of teaching materials.

Achievement Level	Readability Criteria
$60\% < P \leq 100\%$	Easy to understand
$40\% < P \leq 60\%$	Suitable for students
$0\% < P \leq 40\%$	Difficult to understand

3. Results & Discussions

The product developed in this study is in the form of teaching materials of flat side space building based on Problem Based Learning assisted by Assemblr. Teaching materials are developed through three stages, namely define, design, and develop. The following is an explanation for each stage carried out in this study.

3.1. Define

The defined stage contains the final initial analysis activities, student analysis, and task analysis. The final initial analysis aims to establish the fundamental problems in the learning process. The problem found by researchers through literature studies is the weak spatial ability of students in geometry materials. The results of Wulansari & Adirakasiwi's research (2019) stated that most students lack mastery of geometry material, they find it difficult when learning geometry. The results of research by Arifin et al. (2020) revealed that students still have difficulty in constructing geometric spaces, especially in solving problems with visualization. The results of the two studies are in line with the research of Sutadnyana (2013) that is most students find it difficult to solve problems related to three dimensions that require spatial geometry skills so the results obtained are very disappointing. An alternative solution offered by researchers to improve students' spatial abilities is the development of Problem Based Learning-based teaching materials assisted by Assemblr. This is based on previous studies that state that Problem Based Learning and augmented reality can improve students' spatial abilities. The results of research by Pranawestu et al. (2012), Sugiarni et al. (2018), and Wijayanto et al. (2020) revealed that Problem Based Learning can improve students' spatial abilities. The results of Yanuarto & Iqbal's (2022) research revealed that students' spatial abilities can be improved using augmented reality media. One application that can help users create 3D objects for augmented reality is Assemblr (Ryza, 2017). Problem Based Learning with the help of Assemblr will run more optimally if you use teaching materials. This is in line with the statement of Marika et al. (2020) that learning will take place less optimally if it does not use teaching materials, including in mathematics learning.

The second activity is student analysis. Students who study flat-side space building are class VIII students and are mostly 12-14 years old. According to Piaget's theory of cognitive development, at that age students are in the formal operational stage that is, the state in which they get the ability to think abstractly by manipulating ideas in their heads without having to rely on concrete manipulations, they can perform mathematical calculations, think creatively, use abstract reasoning, and imagine the results of certain actions. The spatial ability of students at that age has been able to study objects geometrically and projective abilities have developed (Hasanah & Kumoro, 2021), but previous research revealed that students' spatial abilities are still low so they need to be improved.

The third activity is the analysis of tasks that include the analysis of the structure of the content, analysis of concepts, procedural analysis, and the formulation of goals. Content structure analysis is based on Core Competencies and Basic Competencies on the syllabus to determine learning objectives, competency achievement indicators, and material sequences. In this study, researchers chose basic competencies of 3.9 and 4.9.

Table 3. Content structure analysis.

Core Competencies		Basic Competencies	
3.	Understand and apply factual, conceptual, procedural, and metacognitive knowledge on a simple technical and specific level based on his curiosity about science, technology, art, and culture with insights into humanity, nationality, and statehood regarding visible phenomena and events.	3.9	Distinguishing and determining the surface area and volume of flat side space building (cubes, cuboids, prisms, and pyramids).
		4.9	Solves problems related to the surface area and volume of flat side space building (cubes, cuboids, prisms, and pyramids) as well as their combined.

The analysis of the content structure based on the predetermined KI (Core Competencies) and KD (Basic Competencies) includes the volume and surface area of the flat side space building (cubes, cuboids, prisms, and pyramids) accompanied by examples of the problem.

The concept analysis carried out has the aim of identifying, detailing, and systematically compiling the main concepts that students will learn, as well as relating one concept to another relevant concept, thus forming a concept map. This analysis includes a concept map for flat side space building, class VIII material referring to the Curriculum 2013.

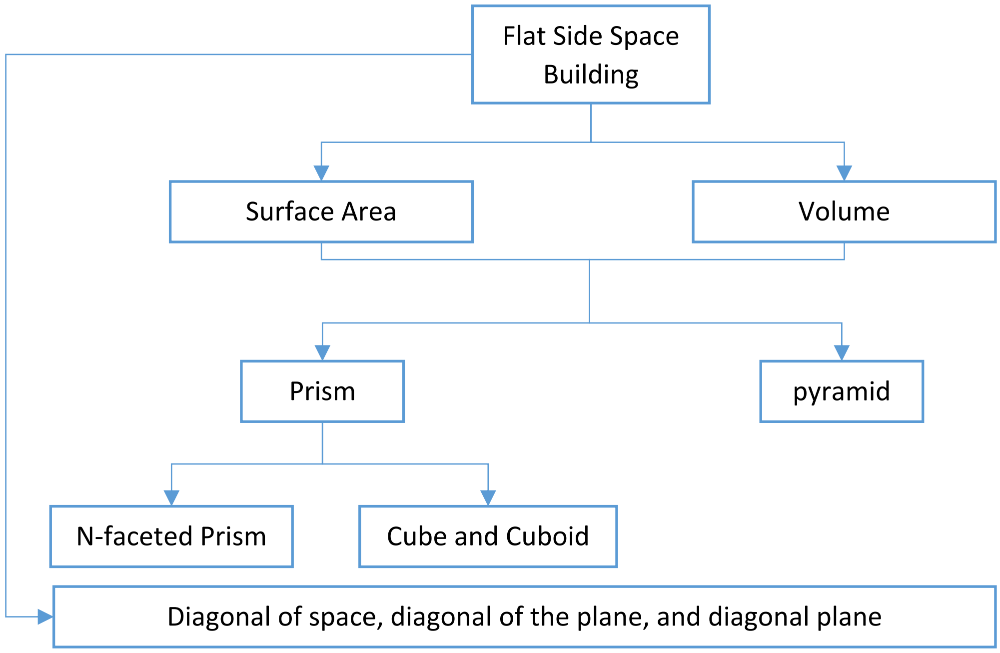


Figure 2. Concept map.

The concepts to be presented are (1) the surface area and construct volume of the flat side space consisting of prisms and pyramids, and (2) the diagonal of space, diagonal of the plane, and diagonal plane. Prisms and pyramids are presented in different chapters. Each of the chapters begins with the notion and properties of the constructive space discussed than its surface area and volume.

The procedural analysis is carried out to identify the stages of task completion and analyze the task by identifying the stages of its completion based on the steps of Problem Based Learning. The Problem Based Learning steps according to Sharma (2012) consist of: (1) problem orientation, (2) organizing learning (3) guiding individual and group investigations, (4) developing and presenting results, and (5) analyzing and evaluating the problem-solving process. The formulation of learning objectives or indicators of achievement of learning outcomes is based on the basic competencies and indicators listed in the curriculum regarding flat-side space building. This formulation includes learning objectives for flat-side space buildings.

Table 4. Formulation of learning objectives.

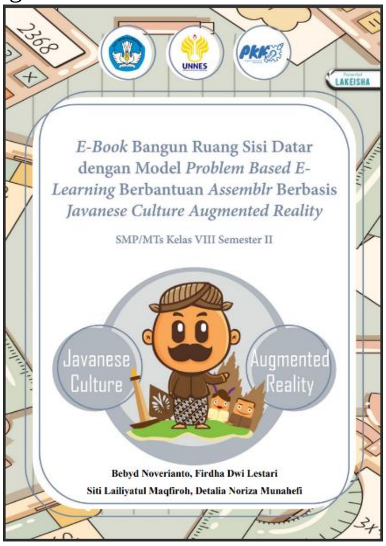
Basic Competencies		Competency Achievement Indicators	
3.9	Distinguishing and determining the surface area and volume of flat side space building (cubes, cuboids, prisms, and pyramids).	3.9.1	Students can know and distinguish both understanding and the properties of flat side space buildings of prisms, pyramids, and diagonals.
		3.9.2	Students can know the formula of surface area, volume, and diagonal relationship.
4.9	Solves problems related to the surface area and volume of flat side space building (cubes, cuboids, prisms, and pyramids) as well as their combined.	4.9.1	Students can solve a real problem related to the surface area and volume of the flat-side space of the prism, pyramid, and diagonal.
		4.9.2	Students can solve problems related to prisms, pyramids, and diagonals.

The learning objectives that can be formulated by researchers from these competencies and competency achievement indicators are that students can: (1) know the meaning and properties of flat side space buildings, (2) distinguish flat side space buildings, (3) know the formula for surface area and the volume of flat side space building, (4) solve the problem of the surface area of flat side space building, (6) solve the problem of the build volume of the flat side space building, (7) solve the daily problems related to the surface area and the build volume of the flat side space building.

3.2. Design

This stage contains activities to design products that have been determined in the defined stage. The steps taken in this activity consist of collecting references, selecting media, and designing teaching materials. Researchers collect various references related to the material which will later become a discussion on teaching materials. The efficiency used varies so that there are no concept errors in the teaching materials developed (Iskandar & Raditya, 2017). In addition, the researcher also selected several examples of objects in the surrounding environment related to flat-side space buildings to be used as problems. After the collection of references, the researcher chose a suitable medium to train students' spatial abilities, namely the Assemblr application. The use of the Assemblr application can help users create 3D shapes from the results of combining various objects and available materials (Ayu et al., 2022). The forms are displayed in the form of augmented reality through the Assemblr application. Explanations related to how to use the assembler are contained in the teaching materials. The next step is the preparation of Problem Based Learning-based teaching materials with the help of Assemblr. This teaching material contains keywords, basic competencies, competency achievement indicators, spatial ability indicators, concept maps, material discussions, material summaries, and evaluations accompanied by answer keys. The appearance of the cover and the content of the teaching materials can be seen in the following picture.

a



b

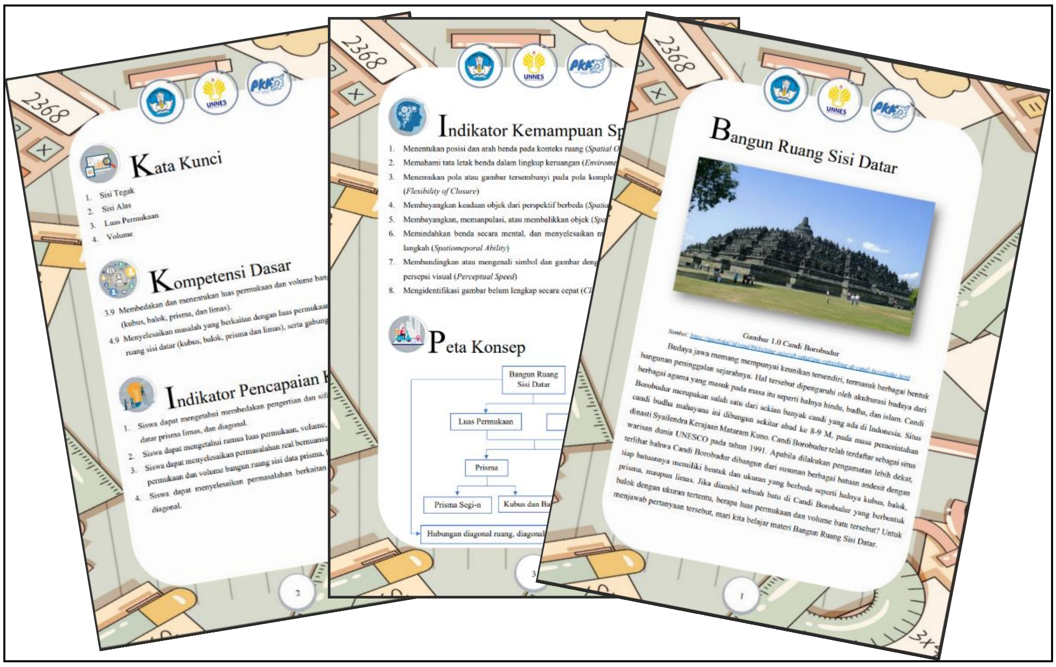


Figure 3. (a) cover view; (b) content display.

Each chapter of this teaching material presents various examples of problems related to flat-side space buildings on real objects. The solution to these problems is based on Problem Based Learning steps. The questions in the evaluation section are arranged based on eight spatial ability indicators. These questions can be used to test students' understanding of the material being studied as well as to train students' spatial abilities.

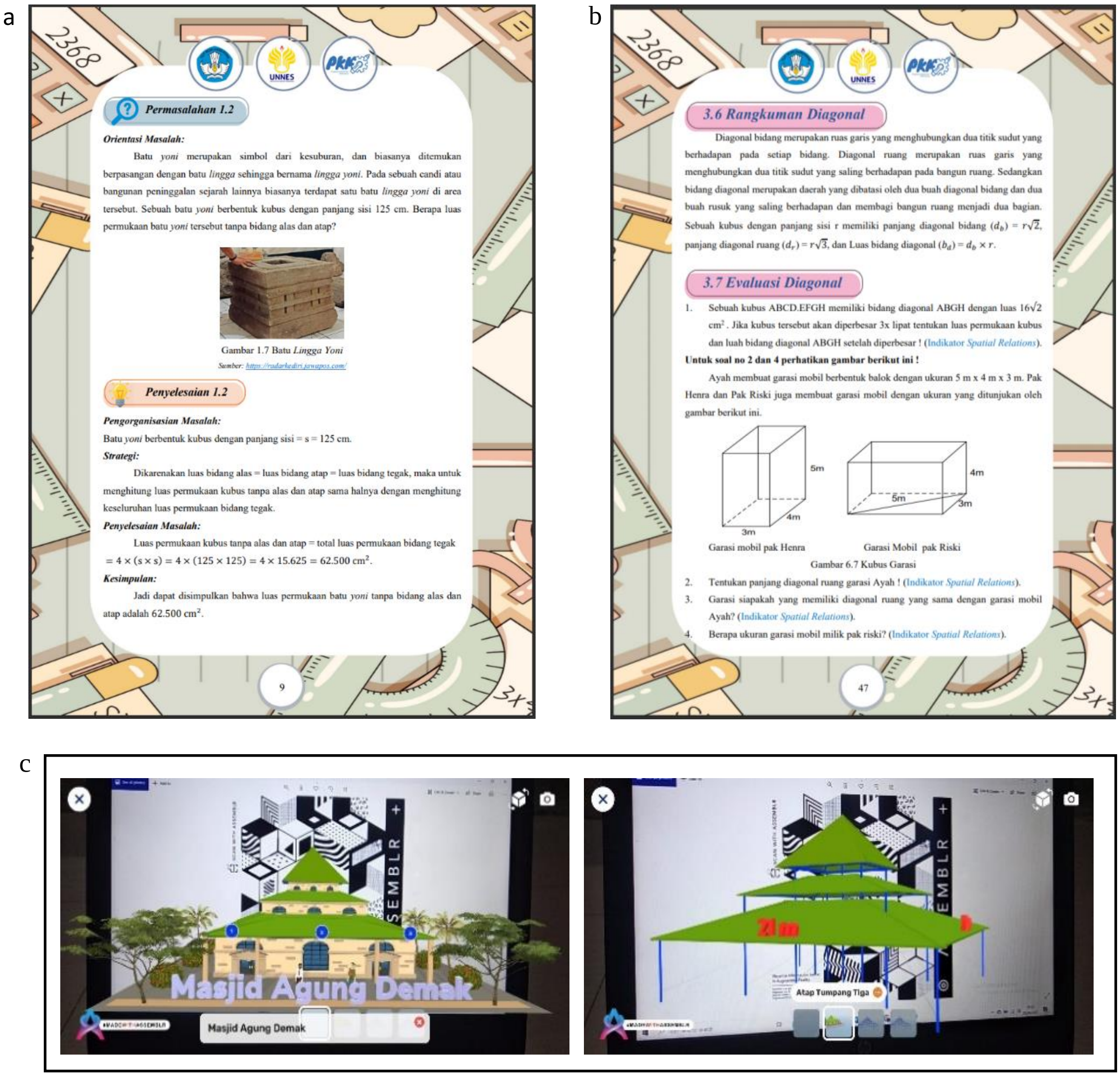


Figure 4. (a) the display of the problem; (b) evaluation display; (c) 3D object display in Assemblr.

3.3. Develop

After the teaching materials are completed, feasibility tests and readability tests are carried out. The feasibility test for teaching materials in this study was given to a mathematics teacher and three mathematics lecturers. The feasibility test results of the four experts can be seen in table 5.

Table 5. The results of the feasibility test of teaching materials.

Aspects	Validators				$\bar{P}$	Criteria Feasibility
	1	2	3	4		
Eligibility of contents	92%	86%	75%	92%	86%	Very worthy
Feasibility of presentation	83%	98%	88%	93%	91%	Very worthy
Language eligibility	98%	88%	84%	93%	91%	Very worthy
Total aspects	91%	90%	81%	93%	89%	Very worthy

According to the results of the feasibility test in the table above, the average percentage of scores obtained for content feasibility is 86%, while the feasibility of presentation and language feasibility is 91%, meaning that the three aspects of the teaching material feasibility test have reached the criteria of being very feasible and do not need to be revised. The feasibility aspect of the content can achieve very feasible criteria because the material on the teaching materials is following basic competencies, achievement indicators, and learning objectives. This is under Zain's statement (2017) that teaching materials should be relevant or have a relationship with the achievement of competency standards and basic competencies. The completeness, regularity, breadth, and depth of the material presented are good. The accuracy of concepts, facts, examples, problems, drawings, and illustrations related to the material presented is exact and correct. The materials, drawings, and illustrations are also assessed as actual. Images and illustrations are very important so that learning materials are easily understood by students (Lestari & Hartati, 2017). The material presented is considered interesting, and can encourage the improvement of learning outcomes and the development of students' mathematical abilities.

Based on the feasibility aspect of the presentation, learning activities in teaching materials are presented using regular and consistent systematics. The presentation of coherent concepts and consistent systematics will help students more easily understand the concepts learned and can motivate students to learn (Azizah & Astuti, 2020). The systematics of presenting teaching materials begins with the provision of material, sample questions, a summary of the material, and finally the provision of evaluation questions. The regularity between competency standards, learning objectives, and material summaries can help students to achieve basic competency (Lestari & Hartati, 2017). The questions in the teaching materials are considered good, meaning that they can spur students to do activities so that students are involved in the teaching materials. The presentation of teaching materials is considered complete and has an attractive appearance. The use of language in Problem Based Learning-based teaching materials assisted by Assemblr is considered straightforward, commutative, following the level of student development, a coherent and integrated thinking flow, consistent in using terms and symbols, and using equations well. Teaching materials are presented using consistent terms so as not to cause confusion in students (Azizah & Astuti, 2020).

The average percentage of scores from the three aspects is 89%, according to the established validity criteria, the overall Problem Based Learning-based teaching materials assisted by Assemblr are declared valid and suitable for use in mathematics learning without the need to be revised. The results of the readability test of teaching materials from three students are presented in the following table.

Table 6. The results of the readability test of teaching materials.

Student name	*P*	Criterion
Amiroh	90%	Easy to understand
Carissa	95%	Easy to understand
Rafa	75%	Easy to understand
$\bar{P}$	87%	Easy to understand

Based on the results of the readability test in table 6 above, the average score percentage is 87%, which means that the material is easy for readers to understand. This is because the teaching materials were developed using simple vocabulary to make it easier for students to understand the material being read (Azizah & Astuti, 2020). According to Jatnika (2007), two factors affect readability, namely language related to word choice, sentence structure, paragraphs, and other grammatical elements, as well as appearance factors related to letters or typography.

4. Conclusion

Teaching materials for flat side space buildings based on Problem Based Learning with the help of Assemblr have been developed through three stages which include define, design, and develop. The results of the feasibility test showed that the teaching materials were declared very valid/suitable for use. The results of the readability test state that the teaching materials can be understood by readers well. The results of the study obtained teaching materials for flat side space buildings based on Problem Based Learning with the help of Assemblr that are suitable for use and easy to understand by readers.

The limited energy, time, cost, and space of dissemination in this study caused the development of teaching materials to only reach the develop stage. This teaching material has obtained a good assessment but has not been tested for the effectiveness of students' spatial abilities. The next study should conduct a trial of this teaching material to students to test its effectiveness on students' spatial abilities. The next research should conduct a trial of the teaching material to students to test their effectiveness on students' spatial abilities.

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