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Development of problem-based learning teaching modules to facilitate the mathematical communication skills of grade VII junior high school students

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Abstract

This study aimed to develop a Problem-Based Learning (PBL) module on flat-sided solid shapes to facilitate the mathematical communication skills of eighth-grade junior high school students. The study employed the 4-D development model consisting of four stages: define, design, develop, and disseminate. The research was conducted in class VIII C of SMPN 1 Rumbio Jaya with 30 students. The results indicated that the PBL-based teaching module was highly valid, achieving average validation scores of 95% for the teaching module, 94% for the student worksheet (LKPD), and 94% for the learning assessment. Practicality testing also showed very practical results, with average scores of 85% in small-group trials and 88% in large-group trials. The findings demonstrate that the developed module effectively facilitates students' mathematical communication skills. Through the PBL phases embedded in the LKPD, students were guided to identify and analyze problems, represent ideas using mathematical symbols and diagrams, and communicate their reasoning in written form. These activities supported the development of key mathematical communication indicators, particularly students' abilities to express mathematical ideas through writing and visual representations.

Keywords: teaching modules; problem-based learning (PBL); mathematical communication skills; flat-sided spatial structures

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I. Introduction

Mathematics is the most important science that supports the progress of science and technology in the era of globalization; to face the challenges and competition of the era of globalization, all students need to be equipped with various mathematical abilities (Mirna, Yulanda, Martin, Jamaris, & Solfema, 2023). One of them is mathematical communication skills, this ability is important in learning mathematics because it can support other mathematical skills (Wannesia, Rahmawati, Azzahroh, Ramadan, & Agustin, 2022). The objectives of the 2013 curriculum and the current independent curriculum also require students to be able to communicate mathematically (Saryantono, & Nurdiana, 2022).

The importance of students' mathematical

communication skills, according to Lubis & Rahayu (2023), is that mathematical communication skills are very important in influencing the learning process to express mathematical ideas through language, notation, or symbols, both orally and in writing. The indicators of mathematical communication skills according to (Wildaniati, Merliza, Loviana, & Mustika, 2021) are written text, drawing, and mathematical expressions. Thus, students' mathematical communication skills enable them to organize and communicate mathematical ideas orally and in writing, understand mathematical concepts in depth, solve problems effectively, and organize and strengthen their mathematical thinking from various perspectives.

In fact, students' mathematical communication skills are still low. This can be seen from the results of research by Yuliani and Vioskha (2022), which state that students are not yet able to communicate questions in the form of pictures, tables, and graphs in this indicator of drawing. Students are still lacking in providing explanations for this mathematical model in the mathematical expression indicator. Students find it very difficult to understand story problems related to everyday life in this indicator written text. Next is research (Alawiyah, 2019) concluded that many students were unable to express mathematical situations in diagrams and algebraic forms (around 60%). Students were still lacking in providing explanations for mathematical models (around 66.7%). Students were still lacking in creating questions from given situations accompanied by reasons (around 86.7%). In line with international study research conducted by PISA (2024), in Indonesia, students' mathematical communication skills are still very low, with Indonesia ranked seventh lowest compared to other countries, due to students' low mathematical thinking skills. According to Greenes and Schulman (2017), mathematical communication is a key strength in formulating mathematical concepts and strategies, so if students have good mathematical communication, it is easier for them to understand mathematics learning. Mathematical communication skills in the field of flat-sided geometric shapes are evident in relevant research findings. The above issues indicate that students' mathematical communication skills are still low.

Based on the problems explained, there is a need for a solution to improve students' mathematical communication skills, including the use of a teaching module (Indrasari, Astuti, & Kurniawan, 2023). This module is designed using a problem-based learning model, enabling students to actively work on real problems and master the expected competencies (Vedianty, & Arif, 2023). There needs to be improvements in the learning process to improve students' mathematical communication skills. To facilitate students' mathematical communication skills, a learning model is needed that places greater emphasis on students' problems, enabling them to play an active role in the ongoing learning process. One of the learning models that can make students active in the learning process and is able to direct students to find the concepts to be learned, namely the model *problem-based learning* by confronting students with real problems in everyday life (Zarkasyi, 2015). Meanwhile, according to Rewel, 2021), to achieve this competence, a learning module was created that teachers could develop as a learning guide, so a teaching module and student worksheets (LKPD) were made to help students facilitate mathematical communication skills.

Some relevant studies are as follows. (Afwa & Astuti, 2023) Conducted a development (R&D) study using the ADDIE model (Analyze, Design, Develop, Implement, Evaluate). The study results showed that the PjBL-based teaching module was considered valid with an average score of 3.83. It met practicality criteria with an average student response questionnaire score of 3.09, which is 77.55%. Meanwhile, the average teacher response questionnaire score was 3.5, or 87.5%. The effectiveness of the PjBL-based teaching module was also demonstrated by an N-gain of 0.36 in a large-scale trial. The similarity between previous research and the study to be conducted is that both are development (R&D)

studies aimed at improving mathematical communication skills, focusing on flat-sided geometric shapes, and targeted at the junior high school education level. The difference lies in the learning approach. Sepriyanti, 2022) is a development (R&D) using the 4-D model. Data collection was done through interviews; the instruments used were a questionnaire, student responses, and test items. The research results, validated by media experts, received validation from 5 validators for the developed mathematics teaching module based on the Group Investigation model, meeting the criteria for very valid with an average of 84.9%. There were also interviews with educators and students about the module that was developed. The practicality results of the developed Group Investigation-based mathematics teaching module meet practical criteria, with averages of 87.3% for educators and 84.6% for students. It can also facilitate students' mathematical communication skills. This is demonstrated by the test results on 12 students, showing that all students scored equal to or above 75 (the minimum competence criteria) with an average of 88%.

Based on the problems presented, the researcher is interested in developing a Problem-Based Learning Teaching Module on flat-sided solid shapes to facilitate the mathematical communication skills of class VIII junior high school students.

II. Research Method

This research aims to develop a teaching module that meets the valid and practical criteria of developmental study, using a PBL model to facilitate junior high school students' mathematical communication skills in the material on flat-sided solid shapes. The development model used in this study is a four-D model consisting of the following stages: define, design, develop, and disseminate.

The instruments used for data collection were validation sheets and teacher and student response questionnaires to assess product validity. Product validation analysis was conducted by determining the final average percentage of the product.

Table 1. Validity assessment indicator

Assessment Aspects	Assessment Indicator
Face Validity	• appropriateness of the supporting presentation • image suitability • suitability of writing
Content Validity	• topic suitability with CP and TP • content accuracy • suitability of content to students' communication level
Construct Validity	• suitability of LKPD with the PBL model • clarity of the LKPD with indicators of mathematical communication skills • clarity of material • accuracy of language use

Source: (Nuramalia, 2024)

Table 2. Practicality assessment indicator

Assessment Aspects	Assessment Indicator
LKPD Display	• Clarity of writing or text on the LKPD so that it can be read • Suitability of color composition, size, and placement of the picture on the LKPD • The image displayed on the LKPD is not blurry • Suitability of space for filling in answers on the LKPD
Content LKPD	• Suitability of presentation of material with steps, PBL, and indicators of mathematical communication skills • The presentation of the material stimulates participant engagement students in learning
Ease of Use of LKPD	• Use language in the LKPD so that it can be understood • Clarity of work orders or instructions on the LKPD, so follow it well • The space provided is sufficient to answer the questions presented

Source: (Sa'dun Akbar, 2017)

The product validity analysis technique is carried out using the formula:

$$V_a = \frac{\boldsymbol{TSe}}{\boldsymbol{TSh}} \boldsymbol{x100\%}$$

Source : (Putri & Reinita, 2023)
Description:
V_a : Validity Percentage
Tse : Total empirical score
TSh : Total maximum score of Product validity criteria

Table 3. Validity analysis techniques

Interval	Category
$81\% < V_a \leq 100\%$	Very Valid
$61\% < V_a \leq c80\%$	Valid
$41\% < V_a \leq 60\%$	Quite Valid
$21\% < V_a \leq 40\%$	Less Valid
$0\% < V_a \leq 20\%$	Very Invalid

Source: (Putri & Reinita, 2023)

The developed teaching module is considered valid and can proceed to the next stage if the score obtained is $\geq 61\%$.

The product practicality analysis technique is carried out using the formula:

$$V_p = \frac{\boldsymbol{TSe}}{\boldsymbol{TSh}} \boldsymbol{x100\%}$$

Source : (Putri & Reinita, 2023)
Description:
V_p : practicality Percentage
Tse : Total empirical score
TSh : Total maximum score of Product practicality criteria

Table 4. Practicality analysis techniques

Interval	Category
$81\% < V_p \leq 100\%$	Very practical
$61\% < V_p \leq 80\%$	practical
$41\% < V_p \leq 60\%$	Quite practical
$21\% < V_p \leq 40\%$	Less practical
$0\% < V_p \leq 20\%$	Very impractical

Source: (Putri & Reinita, 2023)

The developed teaching module is considered practical and can proceed to the next stage if the score obtained is $\geq 61\%$. Adapted from (Sugiyono, 2019).

III. Result and Discussion

Based on the 4D development stages, the definition stage involves analyzing development needs and defining conditions appropriate to the implementation being carried out. At this stage, an analysis of the teaching modules used by teachers, interviews, and observations are carried out. Researchers conducted interviews with two math teachers at SMPN 1 Rumbio Jaya. The interviews and observations revealed that students were experiencing difficulties with the material in flat-sided solid shapes. This was due to the teachers' lack of instruction in using effective learning tools. The existing teaching modules do not reflect the learning process being implemented and are still copies of other teachers' work of a general nature.

References for designing teaching modules to be developed specifically for flat-sided geometric shapes. Students in phase D are grade VIII participants, consisting of teenagers aged 13-15 years. According to Piaget (1945), students at that age already can think abstractly, reason logically, perform mathematical calculations, and draw conclusions. It is known that students who have difficulty understanding flat-sided geometric shapes have difficulty making plans, implementing problem-solving strategies, and solving related problems.

To this end, concept analysis, learning achievement, and task analysis were conducted to obtain the learning objective specifications for each meeting.

The problems identified in the definition stage were then followed by designing a teaching module in the design stage. The test instruments used in this study were validation sheets and practicality sheets. The validation questionnaire was structured based on content and construct aspects. The student questionnaire was structured based on the appearance of the student worksheet (LKPD), content presentation, and ease of use. Print media was then selected as a medium for developing the teaching module. Furthermore, a format was chosen to serve as a guideline in designing the teaching module, consisting of

general information, core activities, and appendices. The developed teaching module is shown in Figure 1.

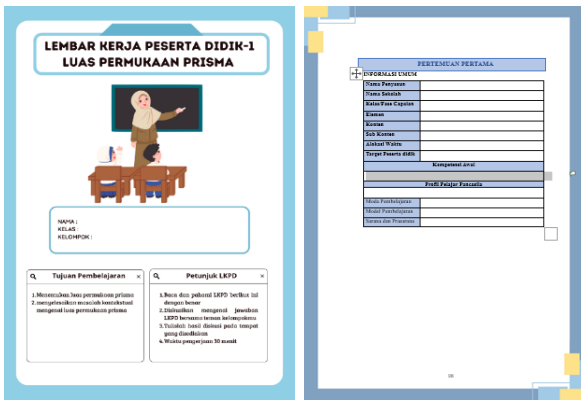

Figure 1. General information and LKPD section display

The expert validation assessment during the development phase was conducted after the learning module was completed. Validation was conducted to obtain an assessment and suggestions for improvements to the developed learning module. Validation was conducted by three validators: two mathematics lecturers and one mathematics teacher. The validators provided suggestions on several components of the learning module to improve it. The following are the validators' suggestions and improvements to the developed learning module.

Kompetensi Awal
Sebelum memulai pembelajaran materi bangun ruang sisi datar, peserta didik harus menyebutkan dan mengidentifikasi kembali mengenai bangun datar, (Seperti, persegi, persegi panjang dan segitiga). Khususnya luas dan keliling : segitiga, persegi, persegi panjang, dan trapesium serta mampu mengidentifikasi sisi, titik sudut, dan rusuk.

Figure 2. View of the teaching module after revision

The validator suggests more specific initial competencies and mentions which plane shapes are most crucial, the validator suggests that meaningful understanding of this material is important to learn, what are the benefits for the students' lives.

The results of the validation of the teaching module by the three validators can be seen in table 5 below.

Table 5. Teaching module validation results

Rated aspect	**The average of the three validators on the teaching module**				**Average (%)**
	1	2	3	4	
Content	98%	98%	98%	98%	98%
Construction	92%	92%	92%	92%	92%
Overall average					**95%**
Criteria					**Very Valid**

Based on the validation results, the teaching module is suitable for testing after improvements were made in accordance with the validator's suggestions. The results of the Student Worksheet Validation for the teaching module can be seen in:

Table 6. LKPD validation results

Rated aspect	**The average of the three validators on the LKPD**				**Average (%)**
	1	2	3	4	
Advance	89%	94%	94%	94%	93%
Content	97%	92%	92%	91%	93%
Construction	100%	92%	92%	100%	96%
Overall average					**95%**
Criteria					**Very Valid**

The results of the assessment validation on the teaching module can be seen in Table 7.

Table 7. Assessment validation results

Rated aspect	**The average of the three validators in the assessment**				**Average (%)**
	1	2	3	4	
Isi	88%	88%	88%	88%	88%
Konstruk	92%	100%	100%	100%	98%
Bahasa	92%	100%	100%	92%	96%
Overall average					**94%**
Criteria					**Very Valid**

Based on Tables 4, 5, and 6, all components of the teaching module have met the validity criteria. After the product was declared valid, a one-to-one evaluation was conducted with three randomly selected students from SMPN 1 Rumbio Jaya. In this test, students commented that some of the language in the questions were still difficult to understand or less communicative, so the researcher revised it to make it more

understandable for junior high school students. Apart from that, there were no problems in completing the LKPD.

Next, a small group trial was conducted with six students at SMPN 1 Rumbio Jaya. The results of the student response questionnaire in the small group are shown in Table 8.

Table 8. Results of the student response questionnaire for the small group trial

Rated aspect	**The average of the three validators on the teaching module**				**Average (%)**
	1	2	3	4	
Display	84%	84%	84%	84%	84%
Content	82%	84%	85%	91%	85%
Usage	82%	84%	86%	90%	86%
Overall average					**85%**
Criteria					**Very practical**

The results of the small-group test are shown in Table 7, which indicates that the LKPD is categorized as very practical. Based on several aspects, namely the LKPD's appearance, material presentation, and ease of use, students understood how to work according to the guidelines. Next, a large-group trial was conducted with 30 students at SMPN 1 Rumbio Jaya. The results of the large group student response questionnaire are shown in Table 8.

During the trial, the researcher was also accompanied by a mathematics teacher to observe the learning process. After the learning activity concluded, the researcher administered a questionnaire to the teachers regarding the use of the teaching module. The questionnaire obtained an average score of 88%, which is categorized as very practical.

Next, a student response questionnaire was given to obtain the percentage of student response questionnaire results in the large group trial, which can be seen in Table 8.

Table 9. Large group test result

Rated aspect	**The average of the three validators on the teaching module**				**Aver age (%)**
	1	2	3	4	
Display	89%	89%	89%	90%	89%
Content	87%	86%	86%	87%	87%
Usage	87%	85%	87%	89%	87%
Overall average					**88%**
Criteria					**Very practical**

Based on Table 8. Overall, it has fulfilled the very practical category with an average of 87%, with comments and suggestions on the questionnaire: "This LKPD is very interesting from the way the questions are presented, it is also very clear, and the appearance is also good."

Result and Discussion

The research conducted was developmental research using a Four-D development model consisting of the define, design, develop, and disseminate stages. The resulting product is a PBL-based teaching module on flat-sided solid shapes to facilitate the development of valid and practical mathematical communication skills among Phase D students.

In the define stage, the activities carried out were initial-final analysis, student analysis, concept analysis, and analysis of learning objective specifications. At this stage, the researcher found a problem, namely that the independent curriculum teaching module had not been 100% realized in the learning process because the teacher did not have good learning tools. The existing teaching module did not reflect the learning process being implemented and remained a copy of other teachers' general results. In addition, the problems found were that students had difficulty understanding problems involving flat-sided geometric shapes, making plans, implementing problem-solving strategies, and solving problems related to flat-sided geometric shapes. Students had difficulty presenting or describing a picture of a geometric shape and writing mathematical symbols. These problems indicate that students' mathematical communication skills are still relatively low. This is in line with research conducted by (Ulymaz, Baidowi, Kurniawan, & Sripatmi, 2022), which stated that students experience difficulties in working on story-based or literacy problems, including difficulty understanding the meaning of the problem and converting it from everyday

language into mathematical form for solving. Students are not proficient at using mathematical terms, symbols, or other forms of language to solve story-based problems.

Based on the problems identified, the researcher chose a problem-based learning model to facilitate mathematical communication skills. By using the PBL model, students are encouraged to be active in understanding and solving problems, as well as developing communication skills. In PBL learning, students not only listen, take notes, and memorize what the teacher explains, but they are also actively involved in the learning process. They are encouraged to communicate their mathematical ideas and present the results they obtain (Siswadi, 2023). This is in line with Surya's (2017) research, which states that the PBL model is a classroom strategy that organizes mathematics learning through problem-solving activities and provides students with more opportunities to think critically, present their own creative ideas, and improve their mathematical communication skills.

In the design stage, there are four activities: preparing standard test validation sheets and practicality sheets, media selection, format selection, and initial design. The teaching module was created in Microsoft Office Word 2016, and the student worksheet (LKPD) was designed in Canva. The preparation of validation and practicality sheets is a step that connects the definition stage with the design stage. Media selection is conducted to identify learning media that are appropriate and relevant to the content's characteristics. Media selection is recommended based on content analysis, task analysis, and analysis of students as users. The chosen media is printed, in the form of teaching modules, because it is easier for teachers and students to use during learning. The teaching module is printed on A4 paper measuring 21 × 29.7 cm. The teaching module consists of a cover page, foreword, table of contents, learning flow and objectives, and a content-based module with general information, core components, and appendices. The design of the teaching module is developed in accordance with the Curriculum Standards and Education Assessment Agency of the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia regarding learning and assessment guidelines.

In the development stage, the designed teaching module was validated by three validators: two Mathematics Education lecturers and a master's degree teacher. The average validation score for the teaching module from the three validators was 95%, which is categorized as very valid. The validation results for the developed Student Worksheet (LKPD) section met the very valid criteria with a percentage of 94%. Furthermore, the validation results for the learning assessment were 94%, categorized as very valid. Based on these validation results, it was concluded that the teaching module had met the validity requirements and was worthy of being tested with revisions. Comments and suggestions from the validators regarding the developed teaching module included the initial competency section, which was not specific and not operational; meaningful understanding was still in the form of learning objectives that did not answer core questions about the material being studied, and the starter questions were too focused on formulas, so that students were not stimulated to think critically and reason. Comments and suggestions on the LKPD included the use of good, correct EYD. The developed teaching module can be tested to determine whether it meets the validity criteria (Anggraini, 2022).

In the one-to-one test, students provided comments and suggestions regarding the small answer space and the language used, which they did not understand. Next, a small group trial was conducted with 6 students. The results of the student response questionnaire for the small-group test showed that 85% of students were categorized as very practical. In the overall LKPD, the appearance aspect of the LKPD had a percentage of 84% in the very practical category. In the overall content aspect of the LKPD, the average percentage was 85% with a very practical category, and the ease aspect of the LKPD had an

average percentage of 96% with a very practical category.

In a large-group test administered to 30 students and observed by one mathematics teacher, the average score was 88%, which is categorized as very practical. The aspect assessed in the practicality of the LKPD is the appearance of the LKPD, which obtained an average score of 89%, categorized as very practical. Overall, the content aspect of the LKPD has an average percentage of 87%, categorized as very practical, and the ease aspect has an average percentage of 87%, also categorized as very practical. The results of the teacher response questionnaire regarding the practicality of the teaching module are 88%, which is categorized as very practical. The aspect assessed in the practicality of the LKPD is the appearance of the LKPD, which obtained an average score of 90%, categorized as very practical. Overall, the content aspect of the LKPD has an average percentage of 89%, which is categorized as very practical, and the ease aspect of the LKPD has an average percentage of 85%, which is categorized as very practical. According to Ramadhani (2023), a teaching module is considered practical if the practicality questionnaire yields an average score>80%.

At the dissemination stage, the researcher packages the product as a book and submits it to the school for use by teachers in the learning process and as a reference for developing teaching modules independently and for online publications.

IV. Conclusion

This research successfully developed a Problem-Based Learning (PBL)-based teaching module on flat-sided solid shapes to facilitate students' mathematical communication skills. The developed module met the criteria for high validity, with an average validation score of 95%, and for high practicality, with average scores of 88% in small groups and 87% in large groups. The use of this module demonstrates that the PBL-based learning model can help students understand problems, plan solutions, implement those plans, and review the results of their work. In addition, this module also increases students' active involvement in the learning process, making them more independent, creative, and critical.

Thus, this PBL-based teaching module effectively improves the quality of mathematics learning and can serve as a reference for teachers in developing learning materials that support the Independent Curriculum. It is hoped that the development of this type of teaching module can be further expanded to include other mathematics content.

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