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The Development of Problem Solving-Based Interactive Learning Media to Improve Mathematical Communication and Self-Regulated Skills

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Abstrak

Penelitian ini bertujuan untuk menghasilkan media pembelajaran interaktif valid, praktis, dan efektif yang dikembangkan melalui model *Problem Based Learning*, menganalisis peningkatan kemampuan komunikasi matematis dan *self-regulated learning* siswa dengan menggunakan media pembelajaran interakitf model *Problem Based Learning*, serta menganalisis proses jawaban siswa dalam menyelesaikan tes kemampuan komunikasi matematis. Penelitian ini merupakan penelitian pengembangan dengan menggunakan model 4D (*Define, Design, Develop, Disseminate*). Subjek penelitian ini adalah siswa kelas 8 SMP. Penelitian ini menghasilkan media pembelajaran interaktif yang berupa RPP, lembar kerja peserta didik, tes kemampuan komunikasi matematis siswa, dan angket *self-regulated learning*. Hasil penelitian ini menunjukkan bahwa media pembelajaran interaktif yang dikembangkan melalui model *Problem Based Learning* valid, praktis, dan interaktif, adanya peningkatan kemampuan komunikasi matematis dan *self-regulated learning* siswa menggunakan media pembelajaran interakitf melalui model *Problem Based Learning*, serta pada proses jawaban, jenis kesalahan yang sering dilakukan siswa dalam menyelesaikan tes kemampuan komunikasi matematika adalah konsep, operasi perhitungan, dan prinsip. Berdasarkan hasil penelitian ini, peneliti menyarankan agar guru dapat menggunakan perangkat pembelajaran ini guna menumbuhkembangkan kemampuan komunikasi matematis matematis siswa.

Kata kunci: *Kemampuan Komunikasi Matematis, Problem Based Learning, Self-Regulated Learning*

Abstract

This research aims to produce valid, practical, and effective interactive learning media developed through the Problem Based Learning model, analyzing the increase in students' mathematical communication skills and self-regulated learning using interactive learning media using the Problem Based Learning model, also analyzing the process of students' answers in solving mathematical communication ability test. This research is development research using the 4D model (Define, Design, Develop, Disseminate). The subjects of this research were class VIII students of junior high school. This research produces interactive learning media in the form of lesson plans, student worksheets, tests of students' mathematical communication skills, and self-regulated learning questionnaires. The results of this research show that the interactive learning media developed through the Problem Based Learning model was valid, practically, and effectively, increased students' mathematical communication skills and self-regulated learning using interactive learning media through the Problem Based Learning model, also in the answer process, the types of errors that students often make in completing mathematical communication ability tests are concepts, calculation operations, and principles. Based on the results of this research, the researcher suggests that teachers can use this learning tool to develop students' mathematical communication skills.

Keywords: *Mathematical Communication Skills, Problem Based Learning, Self-Regulated Learning*

1. INTRODUCTION

Mathematical communication skills are fundamental abilities that students must master in learning mathematics. This is in line with Minister of National Education (Permendikbud, 2016) which explains that the aim of learning mathematics is that students can communicate ideas using symbols, tables, diagrams or other media to clarify situations or problems. This is in line with the National Council of Teacher Mathematics (Branca, 2017) which states that one of the general goals of learning mathematics is learning to communicate mathematics (Ariani, 2017). In line with research by (Lubis, A., dan Harahap, 2017) that one of the mathematical abilities that students must have is mathematical communication skills.

The reason mathematical communication skills are important is because this ability supports other mathematical abilities. In other words, mathematical communication skills are a requirement for students to solve problems. This means that if students cannot communicate well to understand mathematical problems or concepts then they cannot solve problems well. Because the application of mathematical symbols and formulas is part of mathematical communication skills. This statement is reinforced by (Ansari, 2016) who states that there are several reasons why it is important to develop mathematical communication skills in students, namely (1) being able to model situations/circumstances in writing or verbally, graphically, pictures or algebraically; (2) mathematical communication can reflect and clarify thoughts about mathematical ideas in various situations; (3) can develop an understanding of mathematical ideas, for example the role of definitions in mathematics; (4) able to use writing, reading and listening skills to interpret and evaluate mathematical ideas; (5) examine mathematical ideas; (6) able to understand the value of notation and the role of mathematics regarding the development of ideas.

Apart from that, it is confirmed by research by (Yuliani, K., & Saragih, 2015) which states that mathematical communication skills are the ability to express mathematical ideas with symbols, tables, diagrams, or other media to clarify mathematical problems and convey them using mathematical language in teaching and learning mathematics, and can help teachers understand students' abilities to interpret and express their understanding of the mathematical concepts and processes they are learning.

However, expectations are inversely proportional to reality. Mathematical communication skills are still in the low category. Students who have low mathematical communication skills will make it difficult for students to digest the questions given, whereas students who have good communication skills can easily take steps to solve a problem. This can be seen from Sari's research (Hafriani., 2021)which states that if most students are given questions that do not match the examples taught, the students will experience difficulty in solving the questions given, because they do not know where to start to be able to solve the questions. which are given. This was also proven by researchers by giving questions to 30 students in class VIII-2 of SMP Negeri 1 Bandar with the material Cubes and Blocks.

Judging from the explanation of the answers to the communication skills questions from figure 1, it is clear that students do not understand the problem, including students being able to write down ideas for mathematical problems, but students cannot formulate ideas for steps to solve the problem correctly and students also cannot create a mathematical model of the problem. Apart from that, students are less careful so there are errors in solving questions. As a result, if the solution planning is wrong then the answer is also wrong. Students should first replace each quantity in the problem with a variable/letter/symbol to make it easier to work on the problem. From the students' answers, it can be concluded that students lack mathematical communication skills. This is in line with research by (Lestari, 2018) which states that mathematical communication skills that students lack include students being unable to formulate ideas or express situations in the form of correct

mathematical models and students not being able to provide written explanations of conclusions. The following is about mathematical communication skills.

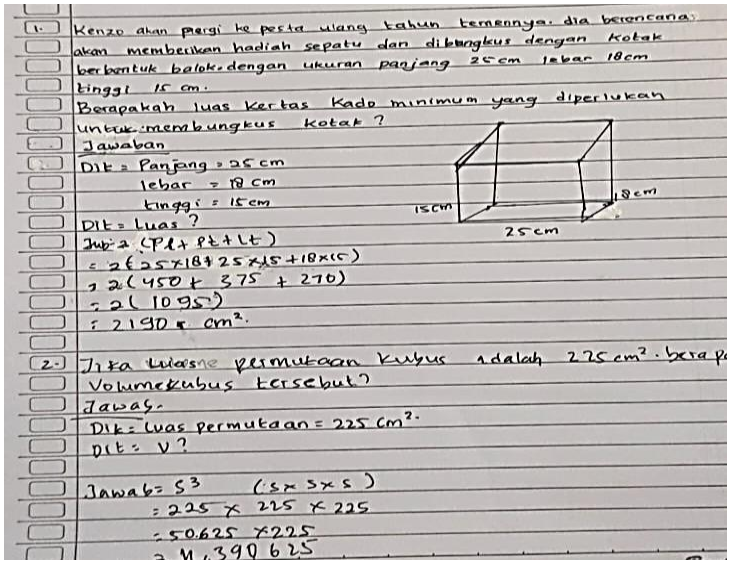

Figure 1. Answer Sheet from One of the Students

This is possibly due to the inaccurate selection of learning models and learning media in the mathematics learning process. It is known that teachers still use direct learning, namely using the conventional model (lecture) so that learning becomes less active. Therefore, when a teacher gives questions that are different from the example questions explained by the teacher, students are less able to work on those questions.

The abilities that students must have are cognitive abilities, affective abilities and psychomotor abilities. Affective abilities are no less important than cognitive and psychomotor abilities in the world of education today. One of the affective domains that is very important for students is self-regulated learning.

In this regard, based on research by (Yuniar, I., Rohaeti, E. E., & Soekisno, 2018), self-regulated learning is an important factor in learning. Self-regulated learning is the ability to direct, control oneself in thinking and acting, and not depend on other people emotionally. (Zimmerman, 2008) say that self-regulated learning (SRL) is a learning process that occurs due to the influence of one's own thoughts, feelings, strategies and behavior that are oriented towards achieving goals. In research by (Pratama, S., Minarni, A., Saragih, 2017), it is explained that independent learning is a need and demand in education today. So it can be concluded that self-regulated learning is a person's attitude regarding something where the individual has independence without being influenced by other people.

The low level of student self-regulated learning is due to the fact that this cannot be separated from the learning system that takes place at school. One of them is influenced by the use of inappropriate learning models and media. In line with the learning model, the majority of teachers in schools have not implemented learning models and media that involve student activities, so the majority of teaching teachers apply conventional learning.

In fact, students who have good self-regulated learning are able to face all problems because they are no longer dependent on other people so they are able to make their own decisions in life. This is in line with research by (Marselina, Vince, 2019)explaining that "students who display more adaptive self-regulatory strategies demonstrate better learning". This means that students who have more

active independence show better learning. Thus it can be said that the independence possessed by a student is able to support his learning abilities. Therefore, learning independence needs to be improved.

In accordance with Mr. Ki Hajar Dewantara's educational motto that in the educational process, teacher behavior is a determining factor in whether the learning system is good or bad. Based on my observations as a researcher, students' low mathematical communication and self-regulated learning skills are related to the mathematics learning scenarios designed by the teacher. It is said to be successful if the scenario can improve this condition. One of the efforts made to improve this condition is through designing good learning, namely using interactive media in collaboration with innovative learning models so that it can improve students' mathematical communication and self-regulated learning skills.

Interactive learning media is learning media that links text, sound, moving images and video with the aim of facilitating the learning process. The use of interactive learning media in the learning process provides many good benefits. The use of interactive learning media is very influential in improving the quality of education. The use of interactive learning media as a learning resource is a strategy in learning. This is in line with Surya's research (Kamarullah, 2017) which states that mathematics learning must be made with exciting and fun strategies so that learning objectives can be achieved.

The above statement emphasizes that teachers must have optimal duties and responsibilities to be able to carry out learning activities well which are characterized by high student activity. If student activity is high, good learning interactions will occur, so that teaching and learning activities will be more effective. Not only teachers are active, but students are also active in learning. Therefore, with students learning more actively, it is hoped that their mathematical communication skills will increase.

The above is also in line with the opinion of (Batubara, 2017) who states that one very important factor in influencing the student learning process is the presence of learning media. The presence of interactive learning media really helps students who are in the concrete operational phase in understanding abstract material. Apart from that, it is also hoped that the presence of interactive learning media can help accompany student learning. Learning media assistance means students are no longer involved in teacher-centered learning. Students have the freedom to learn and develop their abilities, especially mathematical communication skills. The creation of self-regulated learning is one sign that student-centered learning is being implemented. In self-regulated learning, students position themselves as subjects, control holders, decision makers or initiative takers for their own learning. Thus, the ability to control or direct one's own learning is the main requirement.

The interactive learning media assisted by Adobe Flash CS6 which will be developed is very useful for facilitating students so that they can learn independently (self-regulated learning), without having to be explained by the teacher, students can repeat material they don't understand as much as they like until they really understand, Apart from that, the material is also presented interactively, as students are guided directly by the program in carrying out the learning process. Therefore, students who study independently using Adobe Flash CS6 media can make students more active so that their mathematical communication skills increase.

The use of interactive learning media using Adobe Flash CS6 will be more interesting if it is implemented using a learning model that supports students to actively learn. Therefore, so that learning in the classroom using interactive learning media is effective and students are actively involved in the learning process, can improve students' mathematical communication and self-regulated learning skills, teachers need to choose and implement an ideal learning model. One

learning model that is appropriate to use in this problem is the Problem Based Learning (PBL) model.

The problem-based learning model is a model that facilitates students to find problems in complex situations. In this model, students work in groups collaboratively to identify the things needed to learn to solve problems. The problems presented in learning using the problem-based learning model are problems related to everyday life so that the problem-based learning model is suitable for application to mathematics learning.

Problem Based Learning (PBL) is a learning model that requires students to be active in learning activities. In research by (Aufa, M., Saragih, S., Minarni, 2015) stated that the Problem-Based Learning Model (PBM) is one of the innovative student-centered learning models that can provide students with active and creative conditions. This means that the Problem Based Learning (PBM) model is a student-centered learning innovation that can equip students with active and creative conditions. The same thing is in (Sungur, S., Tekkaya, C., & Geban, 2018) research, the problem learning model makes students superior in learning goal orientation, task value, elaboration of learning strategies, critical thinking skills, metacognitive regulation, compared to students who do not apply the problem-based learning model. So to provide activeness in the learning process when implementing interactive learning media, the problem-based learning model is included. Furthermore, research conducted by (Ningrum, 2016) related to problem-based learning can be used as a learning model that can be a means of developing students' mathematical communication skills.

Apart from being able to improve students' mathematical communication skills, The problem based learning (PBL) model using interactive learning media is also a learning model that is able to achieve students' self-regulated learning attitudes. The results of research conducted by (Zainwal, dan Aulia, 2019) stated that the use of Edmodo media in learning can increase students' learning independence in learning using the problem-based learning model. In line with this, research results (Wulandari, 2022) concluded that students' self-regulated learning using the problem based learning model assisted by Edmodo resulted in better achievements than using conventional models.

The aim of developing interactive learning media through the Problem Based Learning (PBL) model is to produce a product that can help students in the learning process in class, change the learning process from students who are told to students who find out, and the assessment process from output-based to output-based. process, so that the product developed can achieve the desired learning objectives, especially in improving students' mathematical communication and self-regulated learning skills.

Based on the description above and the problems showing that the quality of the available learning media is not appropriate and students' mathematical communication and self-regulated learning abilities are still low, it is hoped that the development of interactive mathematics learning media through the problem based learning model will be able to improve mathematical and self-regulated communication skills student learning.

2. METHOD

Based on the problem formulation and research objectives set, this research is categorized into a type of development research using the Thiagarajan, Semmel and Semmel developments, namely the 4-D model (Four D Model) (Sugiyono, 2018). In this research, what was developed was interactive learning media and the necessary instruments. The product in this research is interactive learning media using the Problem Based Learning model that is valid, practical and effective along with all learning media and research instruments needed for the process of developing interactive learning media.

This research was carried out at SMP N 1 Bandar in class VIII odd semester of the 2022/2023 academic year on the material Building Flat Side Rooms (Cubes and Blocks). The reason for choosing this research location was because at SMP N 1 Bandar, research had never been carried out on the development of interactive learning media based on the Problem Based Learning learning model on the material of Building Flat Side Spaces (Cubes and Blocks). The subjects in this research were 30 Class VIII students of SMP N 1 Bandar for the 2022/2023 academic year and the objects in this research were interactive learning media using the Problem Based Learning model with the material of Building Data Side Spaces (Cubes and Blocks) which was developed.

The 4D model consists of 4 stages, namely the definition stage, the design stage, the development stage and the disseminate stage. This research includes the stages of definition, design, development and limited distribution. The dissemination stage was carried out on a limited basis due to limited funds, time and research personnel. The development model in this research is schematically shown in Figure 2. The stages of learning media development are detailed as follows:

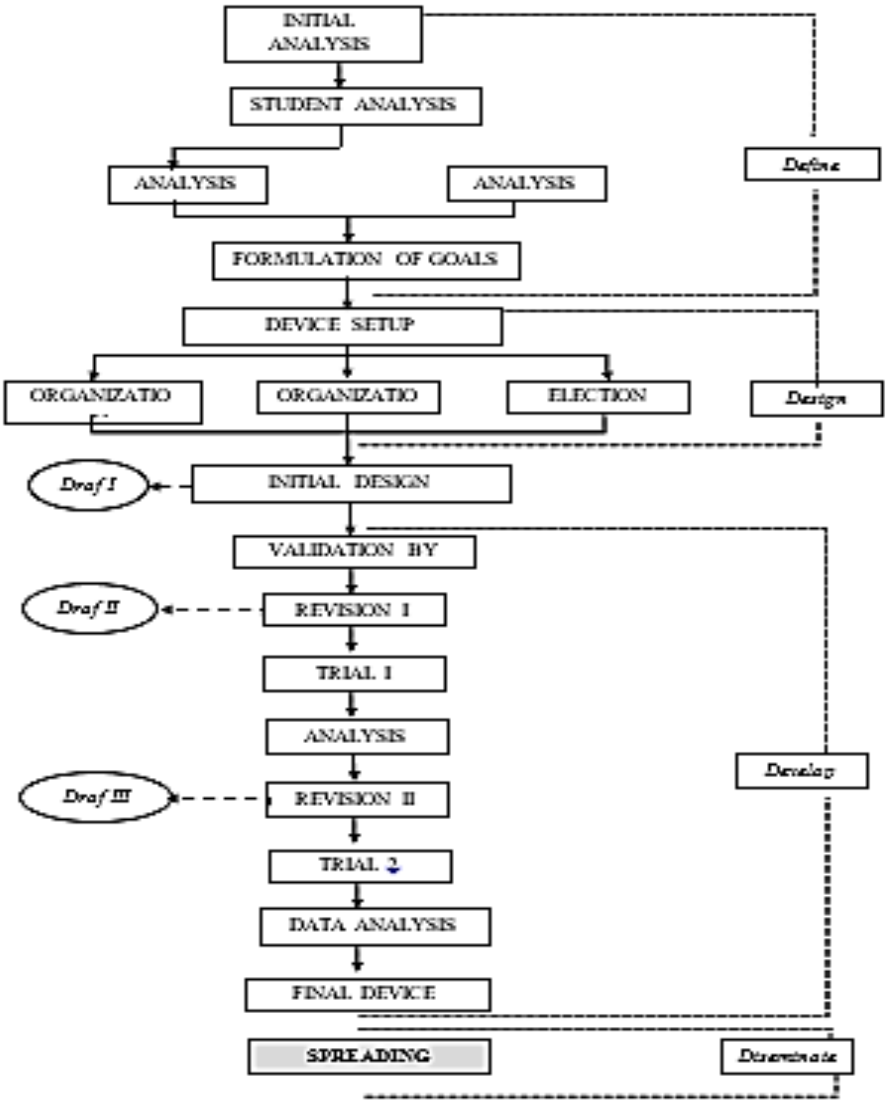

Figure 2. 4D Model Learning Media Development Chart

3. RESULT AND DISCUSSION

The results of the definition and design produce an initial design for a learning tool called draft I. The first phase of the development results is to validate draft I with experts and then carry out field trials. Expert validation focuses on the format, content, illustrations and language of the learning tools developed. The results of expert validation in the form of validation scores, corrections, criticism and suggestions are used as a basis for revising and perfecting the learning tools developed. The following will describe the results of the validation carried out on the learning tools.

Table 1. Recapitulation of Validation Results

No	The object being assessed	Average total validation value	Validation Level
1.	Learning Implementation Plan	4,36	Valid
2.	Student Worksheet	4,32	Valid
3.	Interactive Learning Media	4,65	Valid
4.	Communication Skills	4,42	Valid
5.	Self-Regulated Learning	4,35	Valid

Based on Table 1 above, the total average for each learning device is in range 4-5 with the valid category. According to the validity criteria, it is possible to assert that the newly designed educational module satisfies the valid criteria. The results obtained are then written in the appropriate column in the table. Furthermore, the Va value or total average value is referred to in the interval for determining the level of learning validity as follows in table 2:

Table 2. Learning Validity Level Criteria

No	*Va* atau nilai rerata total	Kriteria Kevalidan
1	1 ≤ Va <2	Tidak Valid
2	2 ≤Va < 3	KurangValid
3	3 ≤ Va <4	Cukup valid
4	4 ≤ Va <5	Valid
5	= 5	Sangat Valid

(Susanto, 2013)

Analysis of the Achievement of Classical Mathematical Communication Skills Trial I
In this research, the level of student mastery was viewed from the students' mathematical communication abilities using a test of students' mathematical communication abilities. This test is given before and after learning takes place, the aim is to find out the level of student mastery and completeness of the subject matter they have studied. So the results of this test will be used as evaluation material for researchers to improve things that need to be done in the second field trial later. A description of the results of students' mathematical communication skills in trial I is shown in Table 3 below.

Table 3. Description of Results of Students' Mathematical Communication Skills in Trial I

Information	Pretest of Students' Mathematical Communication Ability	Posttest of Students' Mathematical Communication Ability
The highest score	79,17	89,58

Lowest Value	33,33	54,17
Average	49,93	75,90

Based on Table 3, it shows that the average mathematical communication ability of students in the pretest results was 49.93 and posttest was 75.90. Furthermore, the level of mastery of students' mathematical communication skills in the posttest results of trial I can be seen in Table 4 below

Table 4. Level of Mathematical Communication Mastery of Trial I Students

No	Value Interval	Pretest		Postest		Category
		The number of students	Percentage	The numbe	Percentage	
1	0 ≤ KKM < 60	22	73,33%	1	3,33%	Very low
2	60 ≤ KKM < 70	5	16,67%	8	26,67%	Low
3	70 ≤ KKM < 80	3	10%	10	33,33%	Currently
4	80 ≤ KKM < 90	-	-	11	36,67%	Tall
5	90 ≤ KKM ≤ 100	-	-	-	-	Very high

Based on Table 4, it shows that in the pretest there were 22 students (73.33%) who had a level of mastery of students' mathematical communication skills in the very low category, 5 students (16.67%) had a level of mastery of students' mathematical communication skills in the low category, 3 people students (10%) have a level of mastery of students' mathematical communication skills in the medium category, and 0 students (0%) have a level of mastery of students' mathematical communication skills in the high category. There are also 0% students' level of mastery of students' mathematical communication skills in the very high category. However, in the posttest, the results showed that 1 student (3.33%) had a mastery level of mathematical communication skills in the very low category, 8 students (26.67%) had a mastery level of mathematical communication skills in the low category, 10 students (33, 33%) have a level of mastery of students' mathematical communication skills in the medium category, 11 students (36.67%) have a level of mastery of students' mathematical communication skills in the high category, while the level of mastery of students' mathematical communication skills in the very high category is none or 0 students (0%). The results of the student self-regulated learning questionnaire can be seen in Table 5 below:

Table 5. Students' Self-Regulated Learning in Trial I

Category	The number of students	Percentage (%)
Very high	2	6,67
Tall	16	53,33
Low	8	26,67
Very low	4	12,33
Total	30	100

Based on Table 5, it shows that the students who got the very high category were 2 students out of 30 students (6.67%), while those who got the high category were 16 students out of 30 students (53.33%), for the low category there were 8 students out of 30 students (26.67%) and for the very low category as many as 4 students out of 30 students (12.33%).

Analysis of the Achievement of Classical Mathematical Communication Skills Trial II
A description of the results of students' mathematical communication skills in trial II is shown in Table 6 below:

Table 6. Descriptions of Results of Students' Mathematical Communication Ability Experiment II

Information	Pretest of Students' Mathematical Communication Ability	Posttest of Students' Mathematical Communication Ability
The highest score	89,58	95,83
Lowest Value	54,17	64,58
Average	75,90	87,63%

Based on Table 6, it shows that the average mathematical communication ability of students in the results of posttest 1 was 75.90 and posttest 2 was 87.63. Furthermore, the level of mastery of students' mathematical communication skills in the posttest results of trial II can be seen in Table 7 below

Table 7. Level of Mathematical Communication Mastery of Trial II Students

No	Value Interval	Pretest		Postest		Category
		The number of students	Percentage	The numb e	Percentage	
1	0 ≤ KKM < 60	1	3,33%	-	-	Very low
2	60 ≤ KKM < 70	8	26,67%	3	10%	Low
3	70 ≤ KKM < 80	10	33,33%	2	6,67%	Currently
4	80 ≤ KKM < 90	11	36,67%	8	26,67%	Tall
5	90 ≤ KKM ≤ 100	-	-	17	56,66%	Very high

Based on Table 7, it shows that in posttest I students (3.33%) had a level of mastery of students' mathematical communication skills in the very low category, 8 students (26.67%) had a level of mastery of students' mathematical communication skills in the low category, 10 people students (33.33%) had a level of mastery of students' mathematical communication skills in the medium category, and 11 students (36.67%) had a level of mastery of students' mathematical communication skills in the high category, while the level of mastery of students' mathematical communication skills was in the very high category. there are 0% students. However, in posttest II, the results showed that there were no students (0%) who had a level of mastery of students' mathematical communication skills in the very low category, 3 students (10%) had a level of mastery of students' mathematical communication skills in the low category, 2 students (6.67 %) had a level of mastery of students' mathematical communication skills in the medium category, 8 students (26.67%) had a level of mastery of students' mathematical communication skills in the high category, while there were 17 students (56.66%) in the level of mastery of students' mathematical communication skills in the very high category. %). The results of the student self-regulated learning questionnaire can be seen in the table 8.

Table 8. Student Self-Regulated Learning in Trial II

Category	The number of students	Percentage (%)
Very high	5	**16,67**
Tall	15	**50,00**
Low	7	**23,33**
Very low	3	**10,00**
Total	**30**	**100**

Based on Table 8, it shows that the students who got the very high category were 5 students out of 30 students (16.67%), while those who got the high category were 15 students out of 30 students (50.00%), for the low category there were 7 students out of 30 students (23.33%) and for the very low category as many as 3 students out of 30 students (10.00%).

Based on the posttest results stated previously, in trial I the percentage of classical achievement of students' mathematical communication skills was 73.33%, while in trial II the percentage of classical achievement of students' mathematical communication abilities was 90%. If we look at the results of classical achievement, the students' mathematical communication skills obtained from the results of trial I did not meet the criteria for classical achievement (>80%), while in trial II they met the criteria for classical achievement.

The results of the research above show that the achievement of students' classical mathematical communication skills with interactive learning media through the problem based learning model that was developed meets the effectiveness criteria. This is supported by (Tanjung, H. S., & Nababan, 2018) concluding that the learning media developed using problem based learning meets the effective criteria shown by the students' individual and classical learning completeness. In line with (Rahayu, 2019) which concluded that the learning media developed based on Problem Based Learning met the effective criteria as indicated by the achievement of classical abilities reaching 80%.

The completeness of student learning is due to the material and problems in the LKPD which are developed in accordance with the conditions of the student's learning environment and refer to problem based learning tools. By implementing problem based learning tools, students will be interested in learning and actively involved in the learning process and in solving problems. Students can construct their own knowledge and make conclusions from the knowledge they have found with guidance and instructions from teachers or friends in the form of leading questions.

This is reinforced by Vygotsky's view, namely that intellectual development occurs when individuals are faced with new and challenging experiences, and when they try to solve the problems raised by these experiences. In an effort to gain understanding, individuals try to link new knowledge with the initial knowledge they already have and then build new understanding.

Vygotsky stated that knowledge will be built through experience and the environment around students. In this experience, individuals connect new knowledge with previous knowledge and construct new meaning. In line with Bruner regarding the Problem Based Learning model, namely the idea of scaffolding. Bruner describes scaffolding as a process when students are helped to solve a particular problem beyond the student's developmental abilities through the help (scaffolding) of teachers, friends or people who are more knowledgeable. By providing assistance (scaffolding) by teachers in the early stages of learning and while they complete their assignments, students will be more active in handling their learning tasks, which will result in more effective learning and have an impact on classical learning completion.

Based on research results and support from previous research and learning theories, it appears that interactive learning media based on the Problem Based Learning model developed can help students achieve classical achievements. Thus, it can be concluded that the use of interactive learning media based on the Problem Based Learning model developed has met the effective criteria in terms of classical mathematical communication skills.

4. CONCLUSION

The interactive learning media developed based on the Problem Based Learning learning model in improving students' mathematical communication and self-regulated learning skills has met valid criteria with an average score of 4.65. Interactive learning media developed based on the Problem

Based Learning learning model has met practical criteria. This is based on: Expert/practitioner assessments state that the tools based on the Problem Based Learning learning model developed can be used with slight revisions. The implementation of interactive learning media developed based on the Problem Based Learning learning model is within good criteria, namely 89.37% in trial II.

The interactive learning media developed based on the Problem Based Learning learning model has met the effective criteria. This is based on: Classical student learning completeness has been achieved in trial II at 90%. Achievement of learning objectives has been achieved in trial II, namely 83.39%. 93.31% of students' responses to learning components and activities have shown a positive response to the interactive learning media components and learning activities developed. The learning time used does not exceed normal learning.

Increasing students' mathematical communication skills by using interactive learning media developed based on the Problem Based Learning learning model on flat-sided geometric material (cubes and blocks) increased from an average of 75.90 in trial I to an average of 87.63 in trial trial II and the N-gain value was 0.49 in trial I to 0.51 in the medium category in trial II. vIncreasing students' self-regulated learning using interactive learning media developed based on the Problem Based Learning learning model on flat-sided geometric material (cubes and blocks) increased from an average of 60.00 in trial I to 95.03 in trial II.

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