Developing Problem-based Mathematics Teaching Materials to Facilitate Problem-Solving Ability Achievement

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Abstract

One of the mathematical skills that the students must acquire is problem-solving ability. The importance of problem-solving in learning is also conveyed by the National Council of Teacher of Mathematics. This study was aimed at developing mathematics teaching materials based on specific problems to improve students' problem solving ability. This was a research and development (R & D) study, employing ADDIE (Analysis, Design, Developmen, Implementation, Evaluation) model. This study was conducted at Elementary School Teachers Education department, Institut Agama Islam Negeri Metro. The validation by two material experts reached 4,67, meaning that the criteria was "very good". Furthermore, it was concluded that the characteristics of the developed teaching material were valid, practical and effective.

***Keywords**: Problem-based learning, Mathematics teaching materials, Problem-solving*

Abstrak

Salah satu ketrampilan matematika yang harus dimiliki siswa adalah kemampuan memecahkan masalah. Pentingnya pemecahan masalah dalam pembelajaran juga disampaikan oleh National Council of Teacher of Mathematics. Penelitian ini bertujuan untuk mengembangkan bahan ajar matematika berdasarkan masalah tertentu untuk meningkatkan kemampuan pemecahan masalah siswa. Ini adalah penelitian dan pengembangan (R & D) studi, menggunakan model ADDIE (Analisis, Desain, Pengembang, Implementasi, Evaluasi). Penelitian ini dilakukan di program studi Pendidikan Guru Madrasah Ibtidaiyah, Institut Agama Islam Negeri Metro. Validasi oleh dua ahli materi mencapai 4,67, artinya kriteria tersebut "sangat baik". Kemudian disimpulkan bahwa karakteristik bahan ajar yang dikembangkan valid, praktis dan efektif.

***Kata Kunci:** Pembelajaran berbasis masalah, bahan ajar matematika, pemecahan masalah*

Introduction

The ability to solve mathematical problems is a skill in students to be able to use mathematical activities to solve problems in mathematics, problems in other sciences and problems in everyday life.[1]The ability to solve problems is very important in mathematics, not only for those who will later explore or study mathematics but also for those who will apply it in other fields of study or in everyday life.[2]

Problem-solving is one of the goals in the learning process in terms of aspects of the curriculum. The importance of problem-solving in learning is also conveyed by the *National Council of Teacher of Mathematics* (NCTM). According to NCTM, the process of mathematical thinking in mathematics learning includes five main standard competencies namely problem-solvingability, reasoning ability, connection ability, communication skills, and representation ability.[3]This low ability will result in the low quality of human resources, which is shown in the low problem-solving ability. This is because so far learning has concentrated more on training in solving problems that are more procedural and mechanistic rather than concentrating on instilling mathematical problem-solving abilities.

One of the lessons that can be expected to improve students' mathematical problem-solving skills is problem-based learning. Problem-based learning is the learning that uses real-world problems as a context for students to learn about critical thinking and problem-solving skills and to acquire essential knowledge and concepts from the learning material.

Problem-based learning (PBL) is a learner who makes problems a basis for students to learn. This is in line with Duch's opinion which states that the basic principle that supports the concept of PBL already exists earlier than formal education itself, namely that learning begins by asking problems, questions, puzzles that make students want to solve them.[4]Whereas Roh states that problem-based learning is a learning strategy in the classroom that regulates or manages mathematics learning around problem-solving and gives students the opportunity to think critically, submit their own creative ideas, and communicate mathematically with their friends.[5] Due to the fact that PBL begins with a problem to be solved, students who are involved to work in a PBL environment have to be skilled in problem solving, creative thinking, and critical thinking. Unfortunately, young children's problem-solving abilities repeatedlty seem to have been seriously underestimated.

Problem-based learning describes an atmosphere of learning that uses problems to guide, drive, move, or direct learning. Problem-based learning begins with a problem that must be solved, and the problem is raised in such a way that students need additional new knowledge before they can solve the problem. Not just trying or looking for the correct single answer, students will interpret the problem, gather the necessary information, recognize possible

[1] Soedjadi, *Memantapkan Matematika Sekolah Sebagai Wahana Pendidikan dan Pembudayaan Penalaran* (Surabaya: Media Pendidikan Matematika Nasional, 1994), 36.

[2] Russefendi, *Pengantar Kepada Membantu Guru dalam Mengembangkan Kompetensinya dalam Pengajaran Matematika untuk Meningkatkan CBSA* (Bandung: Tarsito, 2006), 341.

[3] NCTM, *Principles and Standard for School Mathematics* (Resto, Virginia: The National Council of Teachers of Mathematics .Inc, 2000), 4.

[4] Duch, et.al., *The Power of Problem-Based Learning: A Practical "How To" for Teaching Undergraduate Courses in Any Discipline* (Virginia: Sterling, 2001), 6.

[5] Kyeong Ha Roh, *Problem-Based Learning in Mathematics* (Coloumbus ; ERIC Identifier, 2003), 2.

solutions, assess several choices, and draw conclusions.[6]

Increasing the ability to solve problems can be done through problem-based learning that emphasizes active student involvement so as to enable learning to be more meaningful. Mathematical learning situations, conditions, and activities so that students' mathematical problem-solving abilities can be achieved in accordance with expectations, depending on teaching materials that can facilitate it. Based on these problems, the purpose of this study is to produce teaching materials that can facilitate the achievement of problem-solving abilities.

Problem Based Learning

Problem Based Learning (PBL) is a learning approach that uses real problems as a context so that students can learn to think critically in doing problem-solving aimed at acquiring essential knowledge or concepts from the subject matter.[7]According to Arends,[8] problem-based learning is a learning approach where students work on authentic problems with the intention of developing their own knowledge, developing inquiry and thinking skills, developing independence and self-confidence.

Problem-based learning is an effective approach to teaching high-level processes. This learning helps students to process the information that has been formed in their minds and compiles their own knowledge about the social world and its surroundings. This learning is suitable for developing basic and complex knowledge.[9] However, it should be paid attention that the effectiveness of PBL may depend on students' characteristics and culture shared in the classroom as well as the problem tasks. Those who support PBL believe that when the students develop methods for arranging or building their own procedures, they are incorporating their theoretical knowledge with their practical skill.

Problem-based learning has the following objectives, namely (1) helping students develop thinking skills and problem-solving skills, (2) Learning the role of an authentic adult, and (3) becoming an independent learner.[10] Moreover, PBL in mathematics teaching can also improve the students' critical thinking skill better compared to those who are not taught by PBL methods.[11]

In addition, Barrett formulated the characteristics of PBL as follows[12]:

1. First, the problem is given to students
2. Students discuss the problem in groups. They clarify the facts, define what the problem is. Then they dig ideas based on prior knowledge and find out what must be known (learned) to solve the problem (learning issues are located here). Reason through problems and determine what action is taken on the problem
3. Individual students are actively involved in learning the knowledge needed to solve their problems
4. The students work again in groups to solve problems
5. Presents completion of the problem

[6] Cucu Suhana, *Konsep Strategi Pembelajaran*, Revisi, Cet. IV (Bandung: PT Refika Aditama, 2014), 70.

[7]

[8] Trianto, *Model-Model Pembelajaran Inovatif Berorientasi Konstruktivistik* (Jakarta: Prestasi Pustaka, 2007), 67.

[9] Trianto, *Mendesain Model Pembelajaran Inovatif Progresif* (Jakarta: Kencana Persada, 2011), 92.

[10] Trianto, 94.

[11] Rini Arviana, Irwan and Meira P. Dewi, "Problem Based Learning in Mathematics Education and Its Effect on Student's Critical Thinking", *Advanced Science Letter,* 24 (2018): 1-4.

[12] T. Arrett et al., *Handbook of Enquiry & Problem Based Learning* (Galway: CELT, 2005), 15.

6. See and reassess what they have learned from experience solving the problem.

The steps of problem-based learning are as follows:

Table 1. Steps of PBM

Stage	Educator' behavior stage
The orientation of students to the problem	Educators explain the purpose of learning, explain the logistics needed, submit phenomena or demonstrations or stories to raise problems, motivate students to be involved in solving selected problems
Stage 2 Organizing students to learn	Educators help students to define and organize learning tasks related to the problem
Stage 3 Guiding individual investigations and groups	Educators encourage students to gather appropriate information, carry out experiments, to get explanations and problem-solving,
Stage 4 Developing and present the work	Educators to help students plan and prepare suitable works such as reports, videos, and models and help them share assignments with friends
Stage 5 Analyze and evaluate problem-solving processes	Educators help students to reflect or evaluate their investigations and the processes they use

From the table above, it can be seen that educators begin learning by explaining the objectives to be achieved in learning, describing, and motivating students to engage in activities in problem-solving activities.

Based on the problems studied, students try to make designs, processes, research that lead to problem-solving, so that they build their own knowledge through real experience, then learners identify problems by finding out what things are known, asked, and looking for suitable ways to solve these problems. In investigating and resolving problems, in the process, students use many skills so that they are motivated to solve real problems and educators appreciate the activities of students so that students like to work together.

Problem-solving skill

Problem-solving is a process to overcome the difficulties faced to achieve the expected goals. In mathematics, problem-solving skills must be possessed by students to solve problem-based questions. According to Saad&Ghani[13]problem-solving is a planned process that must be done in order to get a certain solution to a problem that may not be immediately obtained. Polya[14] defines problem-solving as an effort to find a way out of difficulty. While according to Maryam[15]in the results of his research revealed that "the existence of a problem-solving process is one of the important elements in combining real-life problems.

When students are solving mathematical problems, students are faced with a number of challenges such as difficulties in understanding questions because the problems faced by students are not a problem faced by students before. There are several stages of problem-solving introduced by mathematicians and mathematics instructors such as problem-solving stages according to Polya, Krulik and Rudnick, and Dewey. Schoenfeld, as quoted

[13] N.S Saaddan A.S. Ghani, *Teaching Mathematics in Secondary School: Theories and Practices* (Perak: Universiti Sultan Idris, 2008), 120.

[14] G. Polya., *How To Solve It* (New Jersey: Puceton University Press, 1973), 3.

[15] Maryam Sajadi, Amiripour Parvaneh, and Rostamy Malkhalifeh Mohsen, "The Examining Mathematical Word Problems Solving Ability Under Efficient Representation Aspect," *International Scientific Publications and Consulting Services: Journal of Mathematics*, 2013, 17.

by Ellison[16]states that, is not a teaching about strategies that can cause differences in solving problems but more than that where it does not become a difference.

Based on the opinions that have been described, the problem-solving ability is a skill or potential that must be possessed by students using ways that lead to the process of determining the answer to a question. The problem-solving process provides an opportunity for students to play an active role in studying, searching for, and finding their own information or data to be processed into concepts, principles, theories, and conclusions. The ability to solve mathematical problems is a skill to solve mathematical problems in the form of story problems or non-routine questions, which require detailed stages of completion one by one to obtain a solution.

According to Polya[17]there are four stages of problem-solving, namely understanding problems, making plans to solve problems, planning problems, and reviewing the results obtained. The 4 stages of the Polya are as follows:

1. Understanding the Problem

   Understanding the problem can be done if students understand the meaning of all the words used so that they are able to express the problem with their own sentence, for example by identifying information that is known and needed to find solutions, write concepts that are asked, and make the required images or graphics.

2. Make a Plan for Resolving Problems

   Making a settlement plan can be initiated by linking concepts that are known to those that are not known or asked. For complex problems, problem-solving can be carried out into simpler sub-problems in the hope that it will lead to the identification of the steps needed. Linking concepts faced with other material concepts can lead to creative ideas.

3. Carrying out the Settlement Plan

   Doing a settlement plan requires carefulness in writing each step that has been arranged in the second stage. In addition, the calculation carried out requires precision and perseverance to get the results that match the questions asked.

4. Checking Return Results

   At this stage, students are expected to re-check the steps and solutions that have been obtained by looking at their weaknesses and trying to find logical reasons for each step taken.

Indicators of mathematical problem-solving in this study are: (1) understanding the problem and planning problem-solving; (2) make the process of solving a problem; (3) explain or interpret the results according to the original problem, and (4) check the correctness of the results or answers.

Research Methodology

The research used is development research. The products developed in this study are teaching materials in the form of problem-based mathematics LKS to facilitate the achievement of problem-solving abilities. The development research model used is the ADDIE development model (Analysis, Design, Development, Implementation,Evaluation). This research was conducted at the Metro State Islamic Institute at36-semester PGMI students. This

[16] G. J. Ellison, "Increasing Problem-solving Skills in Fifth Grade Advanced Mathematics Students," *Journal of Curriculum and Instruction* 1, no. 3 (2009): 17.

[17] G. Polya., *How To Solve It*, 5.

research was conducted from February to October 2018.

The procedures carried out in developing this teaching material are 5 stages, namely (1) Analysis, (2) Design, (3) Development, (4) Implementation, and (5) Evaluation. The initial stage is an analysis. The things that are analyzed are the needs of third-semester students and curriculum in accordance with the material ratio (comparison).

The results of the analysis phase serve as the basis for designing teaching materials. The things that are done in the design stage are compiling a map of teaching material needs, determining the structure of instructional materials, compiling research instruments, and determining who validates research instruments by experts.

The third stage is Development. This stage consists of two processes, namely the writing of teaching materials and instrument validation by experts. The validity test aims to explore suggestions and assessments of the teaching materials developed. Based on the results of the validation carried out by practitioners the instructional materials developed were then revised for field testing purposes.

The fourth stage is implementation. In this implementation, a trial of valid teaching materials was carried out according to experts, practicality testing was carried out by filling out questionnaires by students, and testing of effectiveness was carried out by problem-solving ability tests. In this final stage evaluation of the results of the fieldtrials were carried out.

The data obtained in this study are 3, namely data on LKS validity, LKS practicality data, and data on LKS effectiveness. The data sources in this study were validators and PGMI students in the third semester. The data obtained were analyzed descriptively. Data validity is obtained from problem-based LKS validation sheets. The data obtained is then calculated using the validity level formula, namely:

$$average\ instrument\ score\ (x) = \frac{score\ obtained}{a\ number\ of\ items\ statement}$$

\Then the x values obtained were classified according to the following criteria.[18]

Table 2 Criteria for scoring instrument validity.

Score Interval	Category
$\bar{X} > 4{,}2$	Very good
$3{,}4 < \bar{X} \leq 4{,}2$	Good
$2{,}6 < \bar{X} \leq 3{,}4$	Sufficient
$1{,}8 < \bar{X} \leq 2{,}6$	Less
$\bar{X} \leq 1{,}8$	Very less

In this study, the instrument was said to be valid if it met the final assessment of the minimum «good» category.

Problem-based LKS practicality data was obtained from the practicality questionnaire of the LKSaddressed to students. The practicality of the worksheet is seen from the components of the guidance aspects, language aspects, and content aspects. The data obtained from the practicality questionnaire of worksheets is described by the data analysis technique using the formula:

$$average\ practical\ score\ (x) = \frac{score\ obtained}{a\ number\ of\ statement\ items}$$

[18] Widoyoko Eko P., *Evaluasi Program Pembelajaran* (Yogyakarta: Pustaka Pelajar, 2009), 238.

Then, the x values obtained were classified according to the following criteria:[19]

Table 3. Criteria for scoring the validity of the response questionnaire

Score Interval	Category
$\bar{X} > 4{,}2$	Very good
$3{,}4 < \bar{X} \leq 4{,}2$	Good
$2{,}6 < \bar{X} \leq 3{,}4$	Sufficient
$1{,}8 < \bar{X} \leq 2{,}6$	Less
$\bar{X} \leq 1{,}8$	Very less

LKS is said to be practical if it meets the minimum «good» category.

While the effectiveness of teaching materials that have been developed is measured on the results of the problem-solving ability test. The data is obtained by analyzing the students> mathematical problem-solving ability test. The steps are as follows:

1. Calculating the problem-solving ability score using the scoring guide in table 4

Table 4. Problem-solvingGuidelines

No	Step Troubleshooting	Score	Description
1	Understanding the Problem	0	Incorrectly interpreting / not understanding / no answer
		1	Interpretation of the question is incorrect / incorrect to interpret some of the questions
		2	Understanding the problem properly
2	Making a Plan of Settlement	0	There is no settlement plan
		1	Make an irrelevant settlement plan
		2	Make a settlement plan that is relevant but incomplete
		3	Make a relevant, complete and correct settlement plan
3	Performing a Settlement Plan	0	Do not carry out a settlement procedure
		1	Performing the correct procedure but not yet complete
		2	Complete procedures and solutions, but the results are incorrect
		3	Complete and correct procedures and solutions
4	Checking Return Results	0	There is no conclusion
		1	There is a conclusion but it is not complete
		2	Conclusions are true and complete engkap
Total maximum score		10	

The method for calculating the final value of problem-solving abilities is as follows:[20]

$$\mathbf{N} = \frac{\text{score obtained}}{\text{maximum score}} \times \mathbf{100}$$

With N as the final value.

[19] Eko P., 238.

[20] Purwanto, *Evaluasi Hasil Belajar* (Yogyakarta: Pustaka Pelajar, 2008), 28.

The score of problem-solving abilities obtained from the calculation is then qualified according to the following table.

Table 5. Qualifications of Mathematical Problem-solving Ability[21]

Score	Criteria
85,00 – 100	Very good
70,00 – 84,99	Good
55,00 – 69,99	Sufficient
40,00 – 54,99	Less
0 – 39,99	Very less

2. From the score of the students in the posttest, problem-solving ability is said to be complete if the students get a value with a minimum category of "good". LKS is said to be effective if the percentage of completeness in learning the classical learning outcome test of students meets the criteria for completing learning in the minimum category of "good" based on the references in table 5.
3. Presenting completeness classically using the following formula:[22]

$$p = \frac{\text{number of completion}}{\text{number of participants taking the test}} \times 100\ \%$$

Information

p: learning completeness of students

Converting the calculation in the next step to show the classical learning mastery category according to the following table 6:[23]

Table 6. Criteria for completing learning assessment

Percentage of completeness	Classification
$p > 80\%$	Very good
$60\% < p \leq 80\%$	Good
$40\% < p \leq 60\%$	Enough
$20\% < p \leq 40\%$	Less
$p \leq 20\%$	Very less

In this study, worksheets were said to be effective if the percentage of completeness in learning classical learning outcomes tests of students fulfilled the criteria for completing learning in the minimum category «good».

Results and Discussion

This research has been carried out using problem-based mathematics LKS to facilitate the achievement of problem-solving abilities. LKS validity data obtained from the problem-based LKS validation sheet are categorized as valid. This is indicated by the values obtained for each aspect as follows.

Table 7. Results of the validation of teaching materials by material experts and media experts.

Aspects	Expert		Average Score	Score
	Material	Media		
Feasibility content	4,5	4	4,25	Very Good
Language feasibility	3,8	4	3,9	Good
Feasibility of presentation	4,2	4	4,1	Good
Feasibility of graphics	4,12	4	4,06	Good
Conclusion			4,07	Good

Based on table 7 it is concluded that the teaching materials in the form of developed LKS are valid and feasible to be tested with good categories in the opinion of material and media experts.

The results of the validation for the questionnaire responses of students are as follows:

[21] Siti Mawaddah dan Anisah Hana, "Kemampuan Pemecahan Masalah Matematis Siswa pada Pembelajaran Matematika dengan Menggunakan Model pembelajaran Generatif (generative learning) di SMPEDU-MAT," *Jurnal Pendidikan Matematika* 2, no. 3 (Oktober 2015): 170.

[22] Eko P., *Evaluasi Program Pembelajaran*, 247.

[23] Eko P., 247.

Table 8. Assessment of Questionnaire Results

Aspects	Validator		Average	Category
	1	2		
Directions	5	5	5	Very Good
Fill	4,5	4,5	4,5	Very Good
Language	4,4	4,6	4,5	Very Good
Average			4,67	

From table 8 it can be concluded that the average assessment or the results of validation by material experts shows that the questionnaire responses of students on the development of teaching materials using problem-based learning to facilitate the achievement of problem-solving skills are in a score of 4.67. This means the results of the assessment by two validators are "very good".

While the results of the validation of the problem-solving ability test sheet are as follows.

Table 9. Results of Assessment of Learning Outcomes Test

Aspect	Validator		Average	Category
	1	2		
Fill	4,6	4,5	4,5	Very good
Language	4	4,6	4,3	Very good
Average			4,4	Very good

From the analysis of table 9, it can be concluded that the average assessment or the results of validation by material experts shows that the learning outcomes test instrument is in a score of 4.4. This means the results of the assessment are "very good". As a result, the instrument was valid and can be used for posttest.

LKS practicality data was obtained from the practicality questionnaire of worksheets given at the third meeting. The results of the LKS practicality questionnaire are categorized as practical.

The results of the questionnaire response to the practicality of the worksheets provided at the third meeting are as follows.

Table 10. Results for Students' Questionnaire Responses

Feasibility aspects	**Score**	**Value**
Content	4,16	Good
Language use	3,83	Good
Presentation	3,31	Enough
Graphics	3,67	Good
Average	3,74	Good

According to table 3, the guideline for classification of the final response questionnaire was obtained as a «good» category. Thus, it can be concluded that based on table 4.5 this LKS teaching material can be said to be practical because it meets the «good» category.

Knowing the response of the students toward PBL classroom is essential.

This is because the environment in PBL classroom appears different from the typical classroom environment that people have by and large considered good, where classes that are well managed and students acquire high scores on standardized tests.

However, this conventional variety of instruction does not enable students to develop mathematical thinking skills well. Instead of gaining a deep understanding of mathematical knowledge and the nature of mathematics, the students in conventional classroom environments many times tend to learn unsuitable and counterproductive conceptualizations of the nature of mathematics. Unlike conventional classrooms, a PBL environment gives a wide opportunity to students to develop their abilities to adapt and change methods to new situations.

Data on LKS effectiveness was obtained from the results of problem-solving ability tests. Data obtained from tests of students' problem-solving abilities show that the highest score obtained by students is 98 and the lowest value was 59. The average value was 85.8.

From the results of the problem-solving ability posttest, it is known that as many as 4 out of 36 students have not achieved the ability to solve mathematical problems with the percentage of classical learning completeness of 11%. Meanwhile, those who had achieved problem-solving abilities were as many as 32 students with a percentage of classical learning completeness as much as 89%.

Based on the analysis of the problem-solving ability posttest results also obtained students who were able to do the stages of the process, namely stage 1 understood the problem as many as 32 out of 36 students were able to understand the problem with a score of 2, for stage 2 made a complete plan of 30 out of 36 students plan for problem-solving with a score of 3, while for those who are able to do stage 3 which is to do a problem-solving plan as many as 26 of 36 students have been able to do that stage with a score of 3.

As for those who have been able to do stage 4, check the results correctly with a score as many as 21 out of 36 students.

Conclusions and recommendations

This research was the development research that produces problem-based LKS (students' worksheet) to facilitate the achievement of old problem-solving abilities. Based on the results of the trials that have been conducted, it can be concluded that the problem-based LKS developed has valid, practical, and effective characteristics.

LKS validation sheet, response questionnaire validation, and learning outcome test validation are declared valid by experts with an average score of 4.07 in the "good" category because each aspect for each type of validation sheet is at an interval of $3{,}4 < \bar{X} \leq 4{,}2$, so that the teaching material is said to be valid.

The LKS was also considered practical because the results of students' responses to problem-based teaching materials to facilitate the achievement of problem-solving skills indicated the criteria of "good" with an average score of 3.74 at interval 3 , 4 <X ¯≤4,2, so that the teaching material is said to be practical.

The teaching materials were effective because based on the results of achievement tests the problem-solving ability shows that the percentage of completeness in learning classical learning outcomes tests reaches 89% or the "very good" category of minimal 80% or predefined "good" category. It means that the teaching material was categorized to be effective.

Based on the results of the research and conclusions, the researcher cansuggest the following: problem-based LKS can be used as an alternative part of mathematics teaching materials to increase students' interest and problem-solving abilities in learning mathematics, and this research is limited to comparison material so that other researches can be done with the material different or conducting similar research by looking at other mathematical abilities.

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