

OPTIMIZING MATHEMATICAL PROBLEM-SOLVING SKILLS AMONG STUDENT THROUGH METACOGNITIVE-BASED TEACHING MATERIALS DEVELOPMENT

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Abstract

This research was conducted to obtain lecture tools (syllabus, SAP, textbooks and worksheets) that use metacognitive strategies, and see the effectiveness of lecture tools in shaping students' abilities to solve mathematical problems. The research design used is ADDIE development research. This research will be conducted on third semester students of the PGSD study program, Faculty of Education and Humanities, Pelita Bangsa University, TA 2022/2023 in the Elementary Mathematics Learning course. This teaching material is declared valid based on the validation results of experts, practitioners and media experts which are marked by the acquisition of a high score so that it is suitable for use.

Keywords: mathematical problem solving skills; metacognitive; teaching materials

Abstrak

Penelitian ini dilakukan untuk mendapatkan perangkat perkuliahan (silabus, SAP, buku ajar dan LKS) yang menggunakan strategi metakognitif, serta melihat keefektifan perangkat perkuliahan dalam membentuk kemampuan mahasiswa dalam memecahkan masalah matematika. Desain penelitian yang digunakan adalah penelitian pengembangan ADDIE. Penelitian ini akan dilakukan pada mahasiswa semester tiga program studi PGSD Fakultas Pendidikan dan Ilmu Budaya Universitas Pelita Bangsa TA 2022/2023 pada mata kuliah Pembelajaran Matematika SD. Bahan ajar ini dinyatakan valid berdasarkan hasil validasi ahli, praktisi dan ahli media yang ditandai dengan perolehan skor tinggi sehingga layak digunakan.

Kata kunci: keterampilan pemecahan masalah matematis; metakognitif; bahan ajar

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Introduction

Talking about the challenges and problems of education in Indonesia entering the era of globalization, it is necessary to prepare educational activities that are able to equip students to face the challenges of life in the future, namely organizing education that is responsive to the era of globalization. To face these challenges, it is necessary to conduct training for students so that they are able to learn independently and develop their reasoning and thinking skills (Ministry of National Education, 2006).

Mathematical problem solving ability is an important ability and must be possessed by every student (Murdiana, 2015). This ability is not only needed in mathematics, but also in everyday life (Apriadi, Elindra, & Harahap, 2021). Problem solving is a way to achieve goals through the application of knowledge and skills possessed. It can be said that the ability to solve

mathematical problems is a skill that makes students able to solve mathematical problems and problems in everyday life.

One of the factors causing the low problem-solving ability of students is the lack of practice in solving problems (Murdiana, 2015). Thus learning mathematics must be taught through a problem solving approach. Learning with this approach involves students in solving problems related to the real world (Ripai & Sutarna, 2019). In this lesson, students are trained in math skills from elementary to high level (Murdiana, 2015).

Mathematical problem solving skills have a very important urgency in Indonesia (Helmon & Sennen, 2020) (Hendriani, Melindawati, & Mardicko, 2021). This is because the ability to solve mathematical problems is one of the important competencies in the 21st century (Helmon & Sennen, 2020). In addition, this ability is also very much needed in everyday life in society and at work. However, there is still a lack of systematic and Indonesian-language reference sources that discuss solving mathematical problems (Suryawan, 2021). Therefore, there is a need for efforts to improve mathematical problem-solving skills in Indonesia, both through learning in schools and through community literacy about the importance of mathematical problem-solving abilities. (Helmon & Sennen, 2020) (Hendriani, Melindawati, & Mardicko, 2021).

Improving the quality of learning is important in order to improve student learning abilities (Sunanto, 2021). This is in accordance with Ronggo Warsito's statement that teachers play an important role in the success of education, therefore (Pendidikan Guru Sekolah Dasar) PGSD students as prospective elementary school teachers must develop their thinking or reasoning abilities. However, what is usually found on the PGSD campus is that the portion of problem solving skills is still lacking (Warsito, 2019).

The problem of solving math problems at the tertiary level includes several things. One of the problems is the lack of students' ability to understand problems, design mathematical models, complete models and interpret the solutions obtained (Rhosyida, Trisniawati, & Putrianti, 2018). In addition, there are problems in the focus of learning mathematics in tertiary institutions which are less directed towards problem solving abilities. Academic problems that often arise based on experience and observation of the learning process are (1) the low desire of students to associate the material they have obtained with the material they will learn, (2) the low desire of students to discuss and ask questions. questions in class, (3) the tendency for students to only receive material from the lecturer, (4) if there are exercises or homework they copy each other, (5) they do not understand the questions or problems, (6) they do not understand the steps for solving mathematical problems and (7) less active discussion.

The above problems are thought to occur due to the low ability of students' mathematical problem solving. The achievement of students' mathematical problem solving abilities is of course influenced by their implementation in the lecture process. In its implementation, of course, the right lecture tools are needed, so metacognitive strategies are used to overcome the problems mentioned above. Metacognition is often referred to as thinking in thinking, as we know that problem solving requires deep or metacognitive thinking to be able to unravel the problem. Therefore, the development of teaching materials is an alternative to hone students' problem-solving skills so that later they are able to solve various problems in learning mathematics and teach it to students.

Stenberg stated that metacognitive abilities grow and develop with age. In general, metacognitive abilities begin to develop around the age of 5 to 7 years. Some older children seem to have better information processing. This is because older children have faster processing of information. The development of metacognitive abilities in children includes understanding and controlling cognitive processes, these cognitive processes are closely related to intellectual

development(Stenberg, 2008). Wellman stated that metacognition is a form of cognition, or a thinking process of two or more levels that involves controlling cognitive activity(Wellmann, 1977). Metacognition can also be said to occur when one is aware of a realization, where one can control his thinking through planning, monitoring and evaluating what he learns (Sunanto & Asyiah, 2018).

Metacognition can be said as one's thoughts about one's own thoughts or one's cognition about one's own cognition. Samuels stated that metacognition also involves one's knowledge and awareness of one's own cognitive activity, or anything related to one's cognitive activity.(Samuels, Jay, & Ann, 2005, p. 43). Thus, a person's metacognitive activities such as planning, monitoring, and evaluating the completion of certain tasks are basically metacognition. Flavell & Brown stated that metacognition is knowledge and regulation of one's cognitive activity in the learning process. This shows that cognitive knowledge is how a person manages his cognitive activity effectively(Samuels, Jay, & Ann, 2005, p. 42).

Each individual's metacognitive abilities will be different, depending on metacognitive variables, namely individual conditions, complexity, knowledge, experience, benefits, and thinking strategies. Metacognitive activity depends on individual awareness, monitoring, and regulation. Metacognitive abilities are believed to improve mathematical problem solving abilities. The results of the study state that there is a relationship between metacognition and mathematical problem solving abilities(Aldiono, Khamsatul M, Rosidi, & Ahied, 2022).

Problem solving is one of the competencies that students will achieve in learning mathematics in addition to conceptual comprehension and communication competencies at the elementary school level. Problem solving needs to be integrated into learning mathematics because by learning problem solving students are expected to be skilled in thinking and reasoning so that in the learning process students do not only rely on memorizing abilities.

The rational reasons underlying the importance of mathematical problem solving abilities are:

- a) Branca argues that solving mathematical problems includes methods, procedures and strategies which are the core and main processes in the mathematics curriculum or the general objectives of learning mathematics, even as the heart of mathematics. In addition, problem solving is one of the basic abilities in learning mathematics(Sumarmo, 2003).
- b) Mathematical problem solving helps individuals think analytically.
- c) Learning to solve mathematical problems is essentially learning to think, reason and apply existing knowledge.
- d) Math problem solving helps to think critically, creatively and develop other math skills.

In addition, according to Conney, teaching students to solve problems makes students more analytical in making decisions in life(Hudoyo & Sutawijaya, 1998). Problem solving in learning mathematics can be defined as the application of concepts and skills which usually involve some combination of concepts and skills in new or different situations. Problem solving is finding the right way to achieve a goal(Santrock, 2014). However, problems in mathematics are problems that students can solve on their own without using routine methods or algorithms. Based on some of these opinions, it can be concluded that solving mathematical problems is the ability shown by students to find solutions or the right way of a mathematical problem by applying various concepts and skills they already have. In learning mathematics, problems that are usually solved include geometry, measurement, algebra, arithmetic numbers and statistics. Mathematical problem solving questions are usually in the form of word problems that require systematic and detailed steps to solve.

The following describes the types of mathematical problems from several experts who distinguish problems in two contexts, namely: (1) Problems are unknown entities in several contexts; and (2) Problems are finding or solving something that is not known to have social, cultural, or intellectual values (Jonassen, 2004).

According to Wijayanti, there are two types of problems, namely: (1) Routine problems are problems that tend to involve memorizing and understanding algorithms and procedures so that routine problems are often considered low-level problems. Routine problems usually refer to problems that only apply certain concepts and procedures, and (2) Non-routine problems are categorized as high-level problems because they require mastery of complex conceptual ideas. Nonroutine problems require creative thinking to solve problems (Widjajanti, 2008). According to mathematics, there are two kinds of problems, namely: 1. The purpose of a problem to find is to find a certain unknown object from the problem. 2. The purpose of a problem to prove is to show conclusively that a certain stated statement is true, or to show that it is false (Polya, 1973, p. 73). Based on the definitions and types of mathematical problems described above, it can be said that a problem is a new situation faced by a person or group that requires a solution and cannot be found immediately with routine procedures. So the math questions in this study are math questions that are not routine for students and are presented in the form of word problems.

In addition, the National Mathematics Teachers' Council explains "Problem solving is an integral part of all mathematics learning, so it should not be an isolated part of the mathematics program" (NCTM, 2000). Problem solving is an integral part of all mathematics learning and thus should not be an isolated part of a mathematics program. In learning mathematics, problem solving is a learning approach that stimulates students to want to think, analyze a problem so that they can determine the solution. Based on the previous explanation, solving mathematical problems in this study uses Polya's problem solving steps.

Polya said "solving problems means finding a way out of a difficulty, a way out of obstacles, reaching a goal that cannot be achieved immediately." The meaning of this statement is that problem solving is an attempt to find a way out of a difficulty, through an obstacle, to obtain a goal that cannot be achieved immediately. According to Polya, there are four stages in the problem-solving process, namely: (1) Understanding the problem. In this step, students must be able to determine what is known and what is asked in the questions or questions given. This must be done before the learner plans and implements a solution plan; (2) Planning a solution. After understanding the given problem or problem, the next step is to develop a solution plan, by considering various things such as diagrams, tables, images or other data, the elements asked in the questions or questions, and also the formulas that can be used. At this step students are required to link the problem with the material that has been obtained by students, so that students can determine the appropriate settlement plan to solve the problem; (3) Carry out the solution plan. The plan that has been prepared is then used to solve the problem by implementing the solution plan that has been made; and (4) Re-checking the solution. The next step is for students to check again or check the answers obtained. (3) Carry out a solution plan. The plan that has been prepared is then used to solve the problem by implementing the solution plan that has been made; and (4) Re-checking the solution. The next step is for students to check again or check the answers obtained. (3) Carry out a solution plan. The plan that has been prepared is then used to solve the problem by implementing the solution plan that has been made; and (4) Re-checking the solution. The next step is for students to re-check or check the answers they have obtained (Polya, 1973). The following describes indicators of problem-solving ability based on Polya's problem-solving stages in Table 1.

Table 1. Indicators of Problem Solving Ability Based on Polya's Problem Solving Stages

No.	Problem solving stage	Indicator
1	Understanding the problem	Students can mention information contained in the questions asked
2	Planning solutions	Students make a problem solving plan in the problem along with the reasons to use the solution
3	Implement a solution plan	Students can solve problems based on pre-planned solutions with correct results
4	Recheck plan	Students re-examine the problem-solving steps <u>which they use</u>

In this study, the reference used to measure the effectiveness of elementary school students' mathematical problem solving abilities was Polya's mathematical problem solving theory, bearing in mind that the steps are simpler and easier to understand.

Research Methods

The development model used in developing the content for the Elementary Mathematics Learning course is the ADDIE model. The reason for choosing the ADDIE model in research on the preparation of teaching materials for Elementary Mathematics Learning courses is because the ADDIE model is carried out systematically in an effort to solve learning problems related to learning tools according to the needs and characteristics of students. The stages of development in the ADDIE model are: (1) analysis, (2) design, (3) development, (4) implementation, and (5) evaluation (Tegeh & Kirna, 2010). The five-stage development procedure can be seen in the development stages chart in Figure 1.

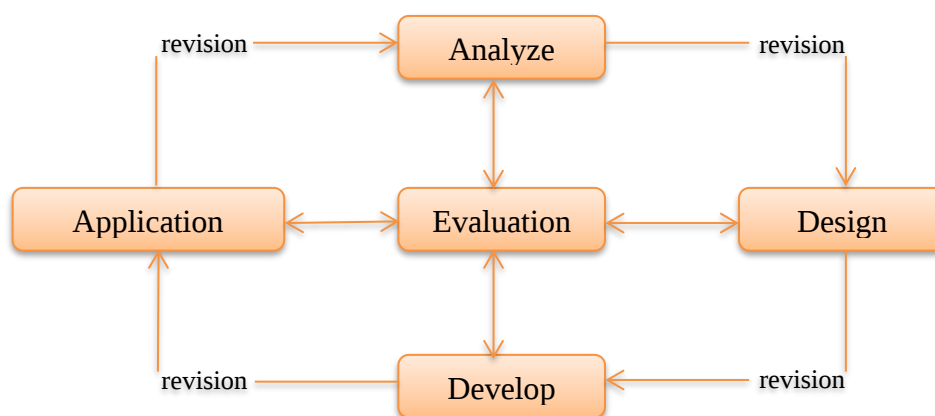


Figure 1. ADDIE Model Development Chart
(Branch, 2009)

The subjects used in this study were third semester students of the PGSD Undergraduate Study Program for the Academic Year 2022-2023, Faculty of Education and Cultural Sciences, Pelita Bangsa University, totaling three classes, and only one class was sampled as a research subject. The subject that is used as the focus of research is the Elementary Mathematics Learning course. The instruments used to obtain the desired data in this study were written test sheets, questionnaires, interviews, and observation sheets. Data collection was carried out through pretest, posttest, questionnaires, observations, and interviews conducted during the learning

process. The processed data are pretest and posttest data collected during the learning process. Quantitative data obtained were then analyzed by looking at the average value.

Results and Discussion

The development research used refers to the ADDIE development model which has 5 steps namely analysis, design, development, implementation and evaluation. These stages are carried out as follows:

Stage 1 analysis; The initial diagnosis of this study was to analyze the curriculum in force at the TTIs of UPB, the learning outcomes of mathematics learning courses in elementary schools, and determine the teaching materials that were developed according to metacognitive strategies. Then proceed with analyzing the characteristics of students, namely students at LPTK UPB, especially the PGSD Study Program, are prospective elementary school teachers who will later guide their students to understand and solve math problems. This is in line with the goals of 21st century education, namely the results of learning activities are expected to be able to make students have the ability to think critically and solve problems, be communicative, collaborative, as well as creative and innovative. Therefore,

Stage 2 Design; Based on the considerations at this design stage, the first thing that must be done is to sort out the material for Elementary Mathematics Learning courses that are more efficiently delivered through metacognitive-based teaching materials. Where the Mathematics Learning course in Elementary School studies the learning of basic mathematical concepts explained in the material: Numbers (number history, place value, number system); Geometry (points, lines, planes, transformations); Measurement; and Data Processing. However, in this study the development will only be focused on Geometry and Measurement materials. At this stage, the researcher also designed pre-test and post-test questions to determine students' mathematical problem solving abilities. The form of the questions can be seen in Figure 2 and Figure 3 below.



Figure 2. Pre-test questions



Figure 3. Post test questions

Stage 3 Development; develop products that have been previously designed and designed, based on designs that have been designed where the products designed are teaching materials in

metacognitive-based Basic Mathematics Learning courses. At this stage the material or materials needed to make a product are teaching materials (Syllabus, SAP, Textbooks and Student Worksheets) on geometry subject matter and measuring aspects supporting metacognitive strategies. Textbooks and worksheets developed for elementary mathematics learning courses can be seen in Figure 4.



Figure 4. Metacognitive-Based Mathematics Textbook

At this development stage a validity test was also carried out and the product design was tested for its effectiveness and practicality. In the validation process, material experts, practitioners and media experts provide suggestions, namely increasing student activity and incorporating character values. Based on input from validators, the textbooks and LKS added steps for student activities in building knowledge and solving mathematical problems, as well as adding character values related to mathematics such as discipline and honesty. The following is a summary of the validator's assessment can be seen in Table 2.

Table 2. Recapitulation of Expert Validator Ratings

No.	Validators	Assessment score
1	Materials Expert	3,4
2	Practitioner	3,1
3	Media Specialist	3,5
	Average	3,3

The average value presented in Table 2 shows that the level of validity of the teaching materials developed is in the very valid category, with an average score of 3.3, which means that the developed teaching materials can be continued to the trial stage. Trial activities are carried out with the aim of obtaining values in the aspects of effectiveness and practicality. The test subjects were 5th semester students who had taught mathematics courses with a sample of 34 students. The test results of teaching materials on students' problem-solving abilities showed a result of 74, so this product was included in the pretty good category in Elementary Mathematics Learning courses. thus the teaching materials developed are ready to be implemented to measure the mathematical problem solving abilities of PGSD students.

Stage 4 Implementation; at this stage the application of metacognitive-based Basic Mathematics Learning courses was carried out. After being declared feasible by the validator, the draft textbook is applied to classroom learning. The implementation of this stage was

attended by 47 Semester 3 students for the 2022/2023 academic year in the PGSD study program. In general, lecturers start the learning process by conveying greetings, learning objectives, apperception and motivation. Furthermore, carrying out the core activities, the lecturer distributes LKM (Student Worksheets) where students carry out lecture activities according to the instructions in the LKM. Students are divided into several groups and then asked to discuss the material and questions at the LKM.



Figure 5. Group Discussion Activities Using Metacognition-Based Teaching Materials

After finishing the discussion, group representatives take turns presenting the results of their discussions in front of the class while being evaluated with the lecturer regarding the results of the discussion and the answers to the questions so that students are able to build and find concepts and be able to solve the math problems given. Then students were asked to work on the questions independently with the aim of knowing the level of effectiveness of using the textbook draft for Elementary Mathematics Learning courses.

TABEL KWL		
Sebelum pembelajaran dimulai, ceritakan apa saja yang kamu ketahui mengenai materi yang dibahas, serta apa yang ingin kamu ketahui terkait materi tersebut dan di akhir pembelajaran tuliskan apa saja yang sudah kamu ketahui terkait materi tersebut!		
WHAT YOU KNOW Pengukuran adalah cara untuk mengukur atau mengukur sesuatu baik berupa angka, maupun penjelasan tentang sesuatu.	WHAT YOU WANT TO KNOW Bagaimana cara mengukur? Apa saja alat yang digunakan dalam pengukuran?	WHAT YOU LEARN Setelah mempelajari materi ini, saya telah mengetahui bahwa pengukuran adalah cara untuk mengukur sesuatu, baik berupa angka maupun penjelasan tentang sesuatu.

Figure 6. Results of Student Metacognition Mapping Through the KWL Table

Stage 5 Evaluation; this last stage is to evaluate or assess the data collected at the implementation stage. The evaluation obtained was carried out to collect data at each stage used to determine the effectiveness of the teaching materials developed. The results of the evaluation carried out on students can be seen in Figure 7, while for students' completeness in using teaching materials in improving mathematical problem solving abilities during the pretest and posttest can be seen in Tables 3 and 4.

Based on Figure 7 it can be seen that after students use the teaching materials of Metacognition-Based Elementary Mathematics Learning, they are able to solve mathematical

problem solving problems properly according to the Polya problem solving stages. The stages of problem solving according to Polya are (1) understanding the problem, (2) planning solutions, (3) implementing solutions, (4) re-examining the results as a whole (Komaria, 2009).

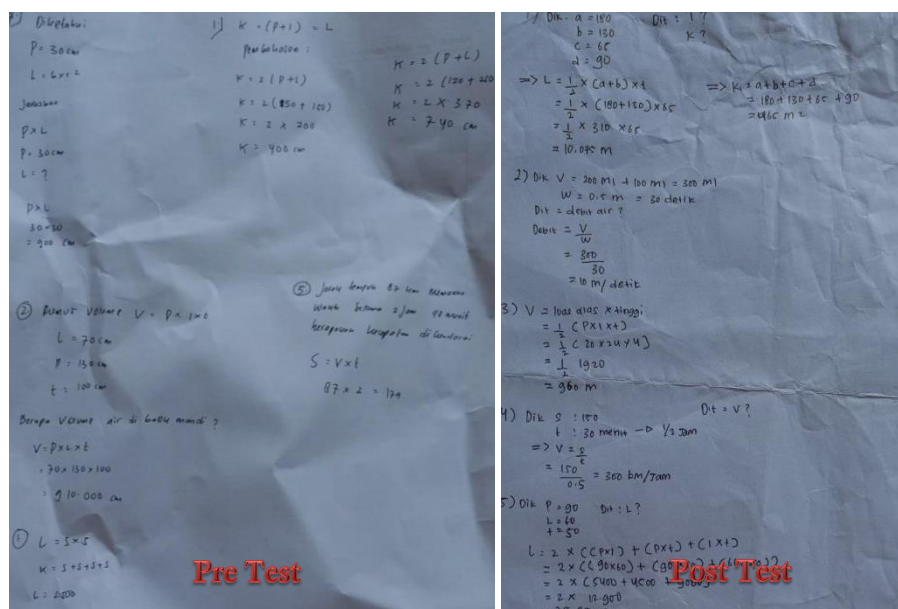


Figure 7. Results of Evaluation of Mathematical Problem Solving Questions

The results of students' mathematical problem solving abilities before and after using Metacognitive-Based Elementary Mathematics Teaching Materials can be seen as follows:

Table 3. Percentage of Mathematical Problem Solving Ability (Pretest)

No.	Value range	Frequency	Percentage (%)	Criteria	
				Meet	Not meet up
1	41-50	16	34.04	-	16
2	51-60	15	46,81	-	15
3	61-70	12	10.64	12	-
4	71-80	3	6,38	3	-
5	81-90	1	2,13	1	-
6	91-100	-	-	-	-
	Total	47	-	16	31
	Percentage (%)	-	100	34.04	65,96

Table 4. Percentage of Mathematical Problem Solving Ability (Posttest)

No.	Value range	Frequency	Percentage (%)	Criteria	
				Meet	Not meet up
1	41-50	1	2,13	-	1
2	51-60	3	6,38	-	3
3	61-70	2	4,26	2	-
4	71-80	11	23,40	11	-
5	81-90	21	44,68	21	-
6	91-100	9	19,15	9	-
	Amount	47	-	43	4
	Percentage (%)	-	100	91.49	8.51

Table 3 shows that the students' mathematical problem solving abilities during the pretest were only 16 students or 34.04% who were able to solve math problems and the remaining 31

students or 65.96% were still unable to solve math problems and according to Polya. solution stages. The data in Table 4 provides information that students who were able to solve math problems were quite high, namely 43 students out of 47 students or 91.49%, compared to those who were still unable to complete only 4 students or 8.51%.

Based on the discussion on each step of the research conducted, it can be said that metacognitive-based learning tools are feasible to use, this can be seen from the average results of validation from material experts, media experts and practitioners with a result of 3.3, the maximum value is 4. After being tested, the results obtained ability solving math problems in elementary mathematics learning courses for PGSD students has a fairly high score by 91.49% of the total 47 students. So that it can be said that the learning tools developed are effective in improving the mathematical problem solving abilities of PGSD students

Thus it can be stated that the use of Metacognitive-Based Elementary Mathematics Learning teaching materials is effective in improving students' mathematical problem solving abilities. This is in line with several research results which state that metacognition is a determinant of success in solving problems (Setyaningrum & Mampouw, 2020), metacognition has a direct influence on problem solving abilities (Ihsan, 2016), and students who are able to solve mathematical problems perform metacognition such as understanding problems, planning, monitoring implementation and evaluating actions at each stage of solving mathematical problems (Hidayah & Nabila, 2022).

Conclusion

Based on the results of research on the mathematical problem solving abilities of PGSD students using teaching materials for Metacognitive-Based Mathematics Learning in Elementary Mathematics Learning Courses with Geometry and Measurement material. It can be concluded that the developed teaching materials are suitable for use, this is in accordance with the validation results of material experts, practitioners and media experts who get an average score of 3.3 which means the teaching materials are valid and suitable for use. to use. Likewise with the results of evaluating the effectiveness of this teaching material, a percentage of 91.49% was obtained, where as many as 43 students were able to solve math problems.

For further research, it is hoped that this teaching material can be developed for other materials in the Elementary Mathematics Learning course in particular and in general it can also be implemented in other mathematics courses.

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