Mathematics module based on problem-based learning to improve students’ metacognition

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Abstract. Low student metacognition can be improved during the teaching and learning process. This study aims to obtain a mathematics module based on problem-based learning valid, practical, and effective. This research is development research. The development model used refers to the development model according to Budiyono. There are 3 stages in this research, namely preliminary study, product development, and product efficacy test. The population in this study was 8th-grade students of junior high school in Surakarta, Indonesia. Schools selection using a stratified cluster random sampling technique. The sample for preliminary field testing is 29 students. The sample for main field testing is 87 students. The instruments used in this study were module assessment sheets, student and teacher response questionnaires, metacognitive knowledge questionnaires, and metacognitive regulation tests. The results of this study are a mathematics module based on problem-based learning are valid based on expert judgment with very good categories, practical based on the assessment of teachers and students with very agreeable categories and effective because of increasing student metacognition after learning using mathematics module based on problem-based learning.

1. Introduction
The success of students can be achieved if learning is done based on the high-quality standards of learning, where students are actively involved in the learning process while the teacher is only a facilitator. In mathematics learning, students are not only required to be able to do a computation, but are also required to understand concepts, reason, and think critically so they can solve problems correctly. In solving problems, it not only involves cognition but also metacognition. This agrees with Susilo and Retnowati [1] which states that metacognition has the main role in the process of solving mathematical problems.

Metacognition is a person's awareness and ability to control their thinking process so they know the right strategy when solving problems. Metacognition consists of two components, namely metacognitive knowledge and metacognitive regulation [2, 3]. Metacognitive knowledge refers to one's knowledge or awareness about tasks and strategies [4, 5]. Metacognitive knowledge consists of declarative knowledge, procedural knowledge and conditional knowledge [6, 7]. Metacognitive regulation is the ability of a person to control his cognitive process [4]. Metacognitive regulation consists of planning, monitoring, and evaluation [8, 9].

Initial research was conducted by giving a metacognitive knowledge questionnaire and metacognitive regulation questions. The metacognitive knowledge questionnaire is used to measure declarative knowledge, procedural knowledge, and conditional knowledge while the metacognitive regulation questions are used to measure planning, monitoring, and evaluation. Based on the results of
metacognitive knowledge questionnaire and metacognitive regulation questions to students obtained 44.94% of students did not know the extent to which they could understand the material taught by the teacher. 56.18% of students were hesitant in solving math problems, 23.6% of students’ learning enthusiasm decreased when learning mathematics, 20.22% of students gave up learning mathematics because they did not understand their intellectual abilities in mathematics, 38.2% of students confused where to start math problems, 46.07% of students studied mathematics only if there were tests, 29.21% of students did not know the right time to use effective learning strategies. Besides, most students are quickly satisfied when they have solved the problem, without knowing whether the solution is correct or not. These things indicate that students’ metacognition is still low.

The low level of metacognition of students must be addressed immediately, because metacognition refers to the regulation of cognitive processes of students to achieve learning goals, namely understanding mathematical concepts [10]. Metacognitive knowledge has an important role in achieving student achievement because metacognitive knowledge influences the use of learning strategies that students will use [7]. The existence of skills or metacognitive regulation makes students more focused on solving problem-solving [11]. This agrees with Mokkos and Kafoussi [12] that argue that metacognition makes students more active problem-solvers because with metacognition students can monitor their thinking and assess whether the steps that have been taken lead to the objectives to be achieved or not. Through the use of metacognition, students can find out what strategies should be used and know what obstacles occur when solving problems. Student metacognition can be improved during the learning process [13].

The results of interviews with several junior high school teachers in Surakarta City, during the teaching and learning process, teaching materials used in schools are revised editions of the 2013 student curriculum books and mathematics textbook available in the market, but the revised edition of the 2013 curriculum book is rarely used even rarely. The reason teachers choose mathematics textbooks available in the market is that students find it difficult to understand the revised edition of the 2013 curriculum book and teachers have not developed their teaching materials to support learning activities. But unfortunately, it has not instructed student metacognition. Also, the mathematics textbooks available in the market does not make students active in learning, learning is still teacher-centered and still provides little real problems in everyday life.

Based on these problems, teaching materials are needed to improve students’ metacognition, enable students to understand the material, to apply their knowledge effectively, and to provide direct feedback to students for each activity they do. One teaching material that can be developed is a module. By using the module as one of the learning resources, students no longer play a role only as listeners and conclusions from a subject, but students also play a role in the process of finding concepts [14]. The module is teaching materials that are systematically arranged which can be used with the guidance of the teacher or without the guidance of the teacher. Modules must describe the basic competence that will be achieved by students, presented using good and interesting language, equipped with illustrations [15]. Besides, the module being developed must fulfill the module characteristics. They are self-instructional, self-contained, stand-alone, adaptive, and user-friendly [16].

Modules need to be supported by a learning model. One such learning model is Problem Based Learning (PBL). The reason for using the PBL model, PBL influences the learning of mathematics, can improve students’ understanding of mathematical concepts and can improve students’ ability to use concepts that have been learned applied in real life [17]. PBL is also student-centered, requiring learners to direct their learning to determine what the key is to know and not to know about problems [18]. This is reinforced by the statement Phungsuk, Viriyavejakul and Ratanaolarn [19] which states that PBL’s focus is on developing students who can devise effective solutions to real-world problems, the more successful those students will become. There are 5 stages in PBL, namely orientation to the problem, organizing students to learn, guiding individual and group investigations, developing and presenting findings, and analyzing and evaluating problem-solving processes [20].

Based on the problems that have been described, this study focuses on the development of mathematics modules based on PBL to improve students’ metacognition. This kind of study had
previously been carried out. The difference is in the study conducted by Anggo and Arapu [21] developing a mathematics teaching aids, while in this study developing teaching material in the form of a mathematical module. In the study conducted by Khayati, Sujadi and Saputro [22] developed a mathematics module based on problem-based learning to improve learning outcomes, while in this study developed a mathematics module based on problem-based learning to improve metacognition.

2. Method
This study is research and development. The development model used refers to the development model according to Budiyono. There are 4 stages in development research [23], but in this study, the stage was modified into 3 stages. They are preliminary study, product development, and product efficacy test. In this paper, the results of product efficacy testing are not presented.

The population in this study was 8th-grade students of junior high school in Surakarta, Indonesia. Sampling using a stratified cluster random sampling technique. The sample for preliminary field testing is 29 students from 1 school. The sample for the main field testing is 87 students from three schools.

The instruments in this study were module assessment sheets by experts, questionnaires for teacher and student responses to modules, questionnaires of metacognitive knowledge and essay test of metacognitive regulation. The instrument module assessment sheet by experts is used to see validity of modules, questionnaires for teacher and student responses to modules are used to see the practicality of the module, and a questionnaire of metacognitive knowledge and essay test metacognitive regulation is used to see the effectiveness of the module.

The data analysis technique in this study was to find out whether the module developed could improve metacognition or not, so experimental research was conducted using the multivariate F test. This is because the metacognition variable consists of two components, namely metacognitive knowledge and metacognitive regulation. However, before the multivariate F test was carried out, it must fulfill the prerequisite test, namely the multivariate normality test.

3. Result and Discussion

3.1 Preliminary study
In the preliminary study phase there are 3 phases, namely initial research, needs analysis and literature study. The initial research was conducted by providing metacognitive knowledge questionnaires and metacognitive regulation essay tests. The result of initial research obtained by most students: 1) decreased enthusiasm for learning when learning mathematics; 2) not knowing their level of understanding after getting material; 3) hesitant in solving mathematical problems; 4) students have difficulty determining the initial steps in solving mathematical problems; 5) study only when there are exams; 6) quickly satisfied when they have solved the problem, without knowing whether the solution is correct or not; 7) not re-checking the completion step.

The results of the needs analysis are done through teacher interviews, most students do not want to ask the teacher or other students when experiencing difficulties, most students cannot manage their time properly when working on problems, teachers need more time teaching algebraic material one of them is a material about systems of linear equations in two variables. Besides, the teaching and learning process of teaching material that is often used is mathematics textbooks available in the market. However, the book does not make students active in learning, gives little real problems in daily life, and has not instructed students' metacognition. Based on the needs analysis it was concluded that mathematics learning on System of Linear Equations in Two Variables (SLETV) requires teaching materials that present real problems in everyday life and some instructions help thinking process students in solving problems. Therefore, teaching materials are developed in the form of a mathematics module based on PBL to improve students' metacognition on SLETV.

The author conducted a literature study by collecting theories about mathematics modules based on PBL and metacognition. Mathematics module based on PBL is teaching materials that are arranged systematically that involve real problems to get new knowledge. Metacognition is a person's awareness
and ability to control his thinking process so that he knows the right strategy when solving problems.

3.2 Product development

Before product development was carried out, the module design and the instrument to be used have been developed. The first step in preparing a module design was to determine the module writing rules and module framework. The writing rules use formats according to ISO, namely A4, ± 60 pages thick, 11 font sizes, Tahoma font types, and Arial Black. The module framework consists of cover pages, preface, table of contents, concept map, glossary, introduction, material, summary, competency test, answer key, bibliography. After that, the products to be developed are made according to the writing rules and module framework.

The product developed in the form of a mathematics module based on PBL is arranged concerning PBL characteristics and PBL syntax. PBL characteristics displayed in the module are problems forming organizational focus and stimulus for learning, problems as a means for developing problem-solving skills, problems become a starting point in learning, the issues raised are problems that exist in the lives of students, and learning occurs in small groups [20, 24]. PBL syntax has been designed to improve metacognition. Next, the application of PBL syntax in the module to improve metacognition is as follows.

The first step of the PBL model is student orientation to the problem. At the beginning of each learning activity, students are presented with problems in daily life about the two-variable linear equation system. These problems bridge students to be able to understand the material well. The problems presented in the module are shown in Figure 1 and Figure 2.

**Figure 1.** The problem I of the module

**Figure 2.** The problem III of the module

Figure 1 shows Problem I presented in the module, Problem I is given to students to bridge students in understanding the material of Linear Equation of Two Variables. Problem III shown in Figure 2 is given by students to bridge students in understanding the material related to the completion of SLETV.

The second step of the PBL model is organizing students to learn. Students are asked to solve the problems presented in the module. In Figure 1 students are asked to solve problems individually, while in Figure 2 students are asked to solve problems in groups. The ability of metacognition trained at this stage is declarative knowledge and planning. In the module in solving problems given instructions to improve declarative knowledge and planning are shown in Figure 3. They are "write the first instruction steps that must be done to solve the problem!", these instructions will help students to know the initial steps of what must be done. Besides, given the instruction "write down what information is known and
as asked about the problem!”, this instruction will help students to choose what information will be used in solving problems and know what problems to solve.

![Figure 3. Instructions to improve declarative knowledge and planning](image)

The third step of the PBL model is guiding individual and group investigations. The problems presented in the module lead students to investigate the problem. The metacognitive abilities trained in this stage are procedural knowledge, conditional knowledge, and monitoring. The module in investigating problems is given instructions shown in Figure 4.

![Figure 4. Instructions to improve monitoring and procedural knowledge](image)

In Figure 4, there are instructions "think about the strategy used to solve the problem!”, this instruction will help students to know how to implement the strategy and when the strategy is used. Besides, given the instructions "make an example and a mathematical model" and "make sure the mathematical model and the model you made are correct", these instructions will help students to monitor the completion step, which is to re-check the math and the mathematical model that is made following the information is known or not.

The fourth step of the PBL model is developing and presenting findings. The completion steps presented by the module can guide students to identify problems and then develop and sort the steps to solve these problems. The ability of metacognition trained at this stage is monitoring. Students after conducting an investigation proceed with a coherent completion step then present the results of the completion.

The fifth step of the PBL model is to analyze and evaluate the problem-solving process. The module presents an answer key which is accompanied by a score to be obtained. The key answers and scores will help students to analyze and evaluate the problem-solving process that has been done.
The ability of metacognition trained at this stage is evaluation, instruction for evaluation is shown in Figure 5.

![Image](image.png)

**Figure 5.** Instruction to improve evaluation

In Figure 5 it can be seen that students are expected to be skilled in evaluating completion. In the student module given an instruction "let’s check the steps that have been done", this instruction helps students to not be easily satisfied with the answers that have been obtained. Students are asked to check the steps that have been taken to ensure that the steps that have been taken are correct. This aims to find out whether there are stages that have been passed or not and whether they have reached the goal or not. The module presents an answer key which is accompanied by a score to be obtained. The key answers and scores will help students to analyze and evaluate the problem-solving process that has been done.

Before the module is tested, the module is validated first using the module assessment sheet by experts. Valid definition in this study is a product that is developed based on strong theory. The experts who assess the module are material experts, media experts, and linguists. A summary of the module assessment results by experts is shown in Table 1.

| Validator     | Average score | Category   | Information |
|---------------|---------------|------------|-------------|
| Material Expert | 3.57          | Very good  | Valid       |
| Media Expert   | 3.54          | Very good  | Valid       |
| Linguists      | 3.5           | Very good  | Valid       |

Based on Table 1 line 2, it can be seen that the material expert validator obtained an average score of 3.57 with a very good category which means valid. In the expert assessment of the material aspects which were assessed consisted of aspects of the appropriateness of the contents, aspects of the presentation, and aspects of the assessment of problem-based learning. The suggestions for improvement from the material expert are to show explicitly the implementation of PBL characteristics in the module, references need to be added, check the editorial editor and on completion using a coherent process.

After the module is repaired following the advice, then the module is reassessed by the material expert. The average score obtained by 3.7 with a very good category which means valid. The results of the material expert assessment for the mathematics module are based on PBL, namely the content of the material in the module is following the school material specified in the 2013 curriculum, the presentation has been arranged systematically, and the PBL syntax applied to the module is clear. It also meets the characteristics of the module, namely independent, independent, and stand-alone. This is because in the module there are clear instructions for using the module, all the material about the SLETVC is contained in the module, and the use of modules does not depend on teaching materials or other learning media.

Table 1 line 3 shows that the media expert validator obtained an average score of 3.54 with a very good category which means valid. The aspects assessed by media experts are the feasibility and graphic aspects. Suggestions for improvement from media expert validators are that the cover design needs to be repaired and the icon used must be replaced because the image is unclear. After the module is repaired...
following the recommendations, the module is then reassessed by media experts. The average score obtained by 3.73 with a very good category which means valid. The results of the media expert assessment for the mathematics module based on PBL display interesting performances to learn and present images that help students understand the material. Besides that, it fulfills the module characteristics namely adaptive. This module can adjust the development of science and is flexible for use in various places.

Table 1 line 4, it can be seen that the linguist validator obtained an average score of 3.5 with a very good category which means valid. Suggestions for improvement from the linguist's validator is the need to pay attention to sentence punctuation, the use of the term must be consistent, cohesion and coherence between sentences need to be observed, there are some typos, misspellings, and non-standard sentences. After the module is repaired following the recommendations, the module is then reassessed by a linguist. The average score obtained by 3.81 with a very good category which means valid. Linguist assessment for mathematics module based on PBL is already using sentences that are easily understood by students and fulfilling the characteristics of the user-friendly module.

Based on the results of the module assessment by experts obtained a valid mathematics module based on PBL. This is following the results of the study by Khayati, Sujadi and Saputro [22] explained that the mathematics module based on PBL meets valid criteria based on expert judgment. After validation and approval by material experts, media experts and linguists are then tested.

In this study, the trials carried out were preliminary field testing and main field testing. Preliminary field testing is conducted to see the practicality of using modules by teachers and students. The instrument used in the preliminary field testing is the questionnaire response by the teacher and students to the module. A summary of the results of the teacher and student response questionnaires are shown in Table 2.

| Response questionnaires | Average score | Category   | Information |
|-------------------------|---------------|------------|-------------|
| Teacher                 | 3.48          | Strongly Agree | Practical   |
| Students                | 3.04          | Agree      | Practical   |

The aspects assessed by the teacher are aspects of presentation techniques, aspects of language suitability, aspects of content suitability, aspects of accuracy, aspects of practicality and convenience, aspects of developing problem-based learning, aspects of improving metacognition. Based on Table 2 Line 2, it can be seen that the response questionnaire by the teacher obtained an average score of 3.48 with the category of strongly agreeing that practical modules are used in learning. This means that the use of a mathematics module based on PBL makes it easy for teachers to teach the SLETV.

Table 2 line 3, can be seen that in the questionnaire responses by students the average score of 3.04 with the agreed categories meant that the practical modules were used in learning. This means that the use of a mathematics module based on PBL makes it easy for students to learn SLETVDV. The aspects assessed by students are the appearance aspect, the material presentation aspect, and the benefit aspect. As for suggestions from students for the module, the completion box must be enlarged, because some boxes do not fit to write answers.

After the revision was carried out following the suggested improvements, then the main field testing was carried out. Main field testing is used to see the effectiveness of using modules, whether or not students can improve metacognition. The instruments used in the main field testing were the questionnaire of metacognitive knowledge and the essay test of metacognitive regulation. The instrument before use is carried out by expert validation and tested. The implementation of the main field testing that is before using the student module is given a questionnaire and essay test about linear equations and inequalities in one variable. After finishing using the module, students are given a questionnaire and essay test about the SLETVDV. The data obtained before using the module is called a pretest, while the data obtained after using the module is called a posttest. The maximum score obtained
from the questionnaire of metacognitive knowledge is 75, while the maximum score obtained from the essay test of metacognitive regulation is 30.

To assess the effectiveness of the module an experimental study was carried out. Data analysis techniques in experimental research used the multivariate F test. This is because the metacognition variable consists of two components, namely metacognition knowledge and metacognition management. But before conducting the multivariate F test, a prerequisite test is a multivariate normality test.

The results of the multivariate normality test on the pretest are the number of squared distances that are less than or equal to $\chi^2_{0.05,2} = 5.991$ there are as many as 86 pieces or 98.85% and this is more than 50%. This means that $H_0$ was not rejected, the conclusion was that the data on metacognitive knowledge and metacognitive regulation in pretest are a multivariate normal distribution. The results of the multivariate normality test on posttest data are the number of squared distances that are less than or equal to $\chi^2_{0.05,2} = 5.991$ there are as many as 84 pieces or 96.65% and this is more than 50%. This means that $H_0$ was not rejected, the conclusion was that the data on metacognitive knowledge and metacognitive regulation in posttest are a multivariate normal distribution.

After the multivariate normality test was fulfilled, it was followed by the multivariate F test. The multivariate F test results obtained $F_{ob} = 263.263$ while $F_{0.05;86} = 3.104$ so that $F_{ob} > F_{0.05;86}$. This means that $H_0$ is rejected, meaning that there is a difference in the average metacognition score between before and after learning using a mathematics module based on PBL. Furthermore, paired t-tests were conducted to find out whether each component (metacognitive knowledge or metacognitive regulation) increased or not. A summary of the results of a paired t-test is shown in Table 3.

| Component of metacognition | N    | $S_d$ | $t_{ob}$ | $t_{0.05;86}$ |
|-----------------------------|------|-------|----------|---------------|
| Metacognitive knowledge     | 87   | 2.021 | 13.421   | 1.662         |
| Metacognitive regulation    | 87   | 3.52  | 20.316   | 1.662         |

Table 3 line 2, it can be seen that the metacognitive knowledge $t_{ob} > t_{0.05;86}$. This means that $H_0$ was rejected. This means that a mathematics module based on PBL can improve metacognitive knowledge. Based on Table 3 line 3, it can be seen that in the metacognitive regulation $t_{ob} > t_{0.05;86}$. This means that $H_0$ was rejected. This means that a mathematics module based on PBL can improve metacognitive regulation.

During learning activities after students have finished studying a sub-material, students are asked to answer some questions in "Let's Know Yourself" and "Test Your Self Ability" shown in Figure 6 and Figure 7.
Based on Figure 6, "Let's Know Yourself" contains questions that serve to increase students' metacognitive knowledge. These questions serve to help students recognize their abilities, how to use strategies and reasons for using strategies when learning and solving problems. Besides, in Figure 7 there is "Test Your Self Ability" which presents questions related to real problems in everyday life and is also presented sheet to fill out answers. On the answer sheet, there are metacognition instructions to help students organize their thinking processes when solving problems. Instructions containing the metacognition process strengthen students' ability to solve problems better because metacognitive strategies increase students' efforts to solve problems [12]. Besides, instructing metacognition to students helps to learn mathematics more actively and understand the material well [21].

Based on the description it can be said a mathematical module based on PBL is effectively used in learning. Effective in this study means that a mathematics module based on PBL can improve students' metacognition. The results of this study agree with the results of research conducted by Ramdoniati, Muntari and Hadiasputra [25] that teaching materials based on PBL can improve metacognition. PBL facilitates students to learn to solve problems, try to plan, evaluate and manage the use of their strategies in solving problems, where it is an activity that can improve metacognition [26]. This finding is in line with the statement that the PBL strategy is a learning model that facilitates students to do investigations so that they can develop critical thinking skills and metacognition [27].

4. Conclusion
Mathematics module based on PBL is valid based on expert and practical based on the assessment of the user (teacher and student). At the main field testing stage, it was found that using a mathematics module based on PBL there was an improvement in students' metacognition. When viewed from each component, there is also an improvement in both metacognitive knowledge and metacognitive regulation. Based on this, a mathematics module based on PBL is effectively used in learning. In subsequent studies, the development of this module can be tested experimentally.

The use of a mathematics module based on PBL in mathematics learning provides excellent benefits for students' metacognition. This is because mathematics module based on PBL can instil an understanding of concepts with students based on their awareness of why and how concepts are constructed and can then use awareness to solve mathematical problems.

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References
[1] Susilo M B and Retnowati H 2018 An analysis of metacognition and mathematical self-efficacy toward mathematical problem solving ability Journal Physics: Conf. Series 1097 012140
[2] Hollingworth R W and McLoughlin C 2001 Developing science students’ metacognitive problem solving skills online Australian Journal of Educational Technology 17 50–63
[3] Jalel S and Premachandran P 2016 A study on the metacognitive awareness of secondary school students Universal Journal of Education Research 4 165–72
[4] Mahdavi M 2014 An overview: metacognition in education International Journal Multidisciplinary and Current Research 2 529–35
[5] Rani R and Govil P 2013 Metacognitive and its correlates: a study Internationa Journal of Advancement in Education and Social Science 1 20–5
[6] Tosun C and Senocak E 2013 The effect of problem-based learning on metacognitive awareness and attitudes toward chemistry of prospective teachers with different academic backgrounds Australian Journal of Teacher Education 38 61–73
[7] Amin I and Sukestiyarno 2015 Analysis metacognitive skills on learning mathematics in high school International Journal of Education and Research 3 213–22
[8] Desoete A, Roeyers H and Buysse 2001 A Metacognition and mathematical problem solving in grade 3 Journal of learning disabilities 34 435–49
[9] Umino A and Dammeyer J 2016 Effect of a non-instructional prosocial intervention program on childrens’ metacognition skills and quality of life International Journal of Educational Research 78 24–31
[10] Izzati L R and Mahmudi A 2018 The influence of metacognition problem solving Journal of Physics: Conference Series 1613 (2020) 012057
[11] Safari Y and Meskini H 2016 The effect of metacognitive instruction on problem solving skills in iranian students of health sciences Global Journal of Health Science 8 150–6
[12] Mokkos E and Kafoussi S 2013 Elementary students’ spontaneous metacognitive functions in different types of mathematical problems REDIMAT-Journal Research in Mathematics Education 2 242–67
[13] Abdolhossini A 2012 Procedia-Social and Behavioral Sciences 46 5898
[14] Rinsiyah I 2016 Pengembangan Modul Fisika Bebasis CTL untuk Meningkatkan KPS dan Sikap Ilmiah Siswa Madrasah Aliyah Jurnal Pendidikan Matematika dan Sains 4 152–162
[15] Departemen Pendidikan Nasional 2008 Panduan pengembangan bahan ajar (Jakarta: Direktorat Jendral Manajemen Pendidikan Dasar dan Menengah)
[16] Daryanto 2013 Menyusun modul bahan ajar persiapan guru dalam mengajar (Yogyakarta: Gava Media)
[17] Padmavathy R D and Mareesh K 2013 Effectiveness of Problem Based Learning in Mathematics International Multidisciplinary e-Journal 2 45–51
[18] Jonassen D H 2008 All problems are not equal: Implications for problem-based learning Interdisciplinary Journal of Problem Based Learning 2 6–28
[19] Phungsuk R, Viriyavejakul C and Ratanaolarn T 2017 Development of a problem-based learning model via a virtual learning environment Kasetsart Journal of Social Science 38 297–306
[20] Rusman 2013 Model-model pembelajaran mengembangkan profesionalisme guru (Jakarta: Rajawali)
[21] Anggo M and Arapu L 2018 The use of mathematics teaching aids to trials metacognition ability of elementary school students Journal Physics: Conf. Series 1028 012143
[22] Khayati F, Sujadi I and Saputro D R S 2016 Pengembangan Modul Matematika Untuk Pembelajaran Berbasis Masalah Pada Materi Pokok Bahasan Persamaan Garis Lurus Kelas VIII SMP Jurnal Elektronik Pembelajaran Matematika 4 608–21
[23] Budiyono 2017 Pengantar metodologi penelitian pendidikan (Surakarta: UNS Press)
[24] Alrahlah A 2016 How effective the problem-based learning (PBL) in dental education The Saudi Dental Journal 28 155–61
[25] Ramdoniati N, Muntari and Hadiasputra S 2018 Pengembangan bahan ajar kimia berbasis problem based learning untuk meningkatkan ketrampilan metakognisi Jurnal Penelitian Pendidikan IPA 5 27–33
[26] Mulyono and Hadiyanti R 2017 Analysis of mathematical problem-solving ability based on metacognition on problem-solving Journal Physics: Conf. Series 983 012157
[27] Danial M, Sawal and Nurilaela 2018 Development of chemistry instructional tools and its effect on critical thinking skills, metacognition, and concept mastery of students Journal Physics: Conf. Series 1028 012041