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Development of Problem-Based Learning Device to Improve Metacognition Ability

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Abstract

The research aimed to produce: (1) a valid, practical, and effective problem-based learning device development product; (2) students' metacognition abilities improvements by using problem-based learning device that have been developed. This research is a development research. The development of problem-based learning device using 4-D models. The products that are produced in this study such as student text book, teacher guide book, lesson plan, student activity sheets, and metacognition ability tests. The subjects in this research were students of second year at State Senior High School 2 Binjai. The result of the first and the second trials are: (1) the problem-based learning device were met the valid, practical, and effective criteria; (2) there was an improvement of students' metacognition abilities by obtained from the n-gain score in the medium category.

Keywords: *Learning Device; Problem-Based Learning; 4-D Development Model; Metacognition Ability*

Introduction

Mathematics is a creative and useful science in which one learns to think (Schoenfeld, 1989). Mathematics is a person's way of thinking about a problem (Richardson et al., 2010). The way of thinking developed in mathematics uses consistent and accurate rules of reasoning which are very effective in looking at various problems in everyday life (Suryadi, 2007). Mathematics is also referred to as an activity which on the one hand is building a theory and on the other hand is solving problems (Otte, 2003). The success of studying mathematics for students means that it has opened up brilliant career opportunities, and for a country, mathematics will prepare its citizens compete in the fields of economics and technology (National Research Council, 1989).

Learning mathematics today is training or developing higher order thinking skills (Kemendikbud, 2018). High-order thinking will occur when a person has information stored in memory and acquires new information, then connects, and/or collects and develops that information to achieve a goal or obtain possible answers/solutions to a confusing situation (Lewis & Smith, 1993).

The ability to think at a higher level is defined as a thought that occurs at a high level in a cognitive process. According to Bloom's taxonomy, which has been revised, higher order thinking skills

are related to cognitive abilities in analyzing, evaluating, and creating (Anderson & Krathwohl, 2010). Basically, higher order thinking skills include higher order thinking skills. For example, to be able to solve a problem, students must be able to analyze problems, think of alternative solutions, implement problem solving strategies, and evaluate the methods and solutions applied. Higher order thinking skills include critical, logical, reflective, metacognitive, and creative thinking skills (Sani, 2019).

Metacognition ability is a person's knowledge of cognitive processes and products (Flavell, 1979). Through metacognition one thinks in order to develop strategies for solving problems (O'Neil & Brown, 1997). Students who have low metacognition abilities will lead to problem solving failures, while students who have good metacognitive abilities will improve non-routine problem solving abilities (Yong & Kiong, 2005). Students who have high levels of metacognitive abilities are expected to clearly: (1) explain what is related to the assigned task; (2) provide specific methods (strategies) for problem solving; and (3) explain when and why to use this strategy (Rompayom et al., 2010).

A major problem in the area of research on metacognition is the adequacy of assessment techniques designed to measure metacognition (Wolter, 1987). Although efforts to measure students' metacognition are still difficult, there is still a need to develop more effective instruments that are furthermore more precise to assess metacognitive abilities (Rompayom et al., 2010). However, to find out students' metacognition abilities, several questions can be asked related to the three stages of metacognition activities which ultimately lead to metacognition indicators, namely planning, monitoring, and evaluation (TEAL, 2012). In fact, the ability of metacognition is still low, especially in the monitoring and evaluation indicators (Sa'adah & Handhika, 2018; Siregar et al, 2019;Rasmitadila et al, 2018). The results of other studies found errors in students in representing the cognitive process. Even though students write the results of the answers correctly, what the students say is not in accordance with what they do (Chairani, 2016).

The teacher is an important figure in teaching mathematics in schools. Before the teacher teaches, a teacher is expected to prepare the material to be taught, prepare teaching aids to be used, prepare questions and directions to provoke students to be more active in learning, learn about students' conditions, understand students' weaknesses and strengths, and learn students' initial knowledge, this will decompose its implementation in the learning device (Suparno, 2002). The learning device is a form of preparation made by the teacher before carrying out the learning process. Teaching preparation is part of a teacher's success. If planning to fail is tantamount to planning failure. This suggests the importance of preparing for learning through the development of learning device (Samsiyah, 2016; Rachmadtullah, et al ,2018; Sumantri, et al 2016, Saputra, et al 2019). The learning device needed in the learning process consist of lesson plans, student text books, students activity sheets, learning outcomes tests and learning media (Trianto, 2011).

The reality of mathematics learning that has occurred so far has less emphasis on enabling students to construct knowledge, so that students do not understand concepts and are unable to solve problems (Sinaga, 2015). The results of the observations show that the mathematics learning model in schools currently does not refer to a particular learning theory. In the learning process in the classroom, students are given common problems that can be solved with simple analysis and mechanistic solutions (Surya & Syahputra, 2017; Supriatna et al 2019; Rachmadtullah et al 2019).

Almost all of the teachers carry out learning using a teacher-centered paradigm. They start learning by providing explanations or examples of the material to be discussed without linking to the real world context then proceed with giving assignments that are similar to examples of problems and end by giving assignments (Saragih et al., 2017; Saputra et al 2020; Rachmadtullah et al 2019). The learning process that does not facilitate students to think outside the context, imagination, decision making and creativity causes students' high-level thinking skills to be low (Samo et al., 2017).

This problem needs to be solved by choosing a constructivist-based learning model, because constructivist-based learning has the potential to empower higher-order thinking skills (Prayitno, 2017; Minarni & Napitupulu, 2020). One of the constructivist-based learning models is a problem-based learning model. Problem-based learning can help students to develop their thinking, problem solving, and intellectual abilities (Arends, 2012).

The next fact is that developing and implementing teaching materials that contain appropriate mathematical assignments to enable children to actively use their high-level thinking skills is seen as difficult for both teachers and researchers in mathematics education in general (Suryadi, 2007). So, the teaching materials are importance in learning activities so that their development is highly demanded by teachers. Based on research, students who were taught using teaching materials had a better score than students who were taught without teaching materials (Olayinka, 2016). Therefore, development of problem-based learning device is expected to be able to improve students metacognition ability.

Method

This type of research is development research. Development of learning device based on the Thiagarajan development model or often referred to as the 4-D model. The development stage consists of the definition stage, the design stage, the development stage and the disseminate stage.

This research was conducted in State Senior High School 2 Binjai on August 13, 2019 until September 3, 2019. The subjects in this study were students of second year at State Senior High School 2 Binjai in the academic year 2019/2020, while the object in this study was the problem-based learning device development product on linear program topics. The development of learning device is in the form of lesson plans, student text books, teacher guide books, student worksheets, and research instruments in the form of metacognition ability tests.

The development of learning device is said to be successful if it meets the quality criteria for development products such as relevant and consistent (validity), practical, and effective (Nieveen & Folmer, 2013). Learning device is said to be: (1) valid, if the minimum level of validity are in the valid category obtained from the expert assessment (Sinaga, 2008); and the instrument has a minimum level of pretty good obtained from reliability test (Lestari & Yudhanegara, 2017); (2) practical, if implementation of learning device can be classified well obtained from observation (Minarni et al., 2020); (3) effective, if at least 85% of students obtain a minimum grade of B- (Trianto, 2011) and students mark positive perception to and response towards the learning device (Minarni & Napitupulu, 2017).

To analyze the improvement of students' metacognition ability after using problem-based learning device is determined by the N-gain formula, as follow:

$$N-gain\ (g)=\frac{posttest\,score-pretest\,score}{ideal\,score-pretest\,score}$$

The criteria of normalized gain score are: (1) high, if $g > 0.7$; (2) medium, if $0.3 < g \leq 0.7$; and low, if $g \leq 0.3$ (Hake, 1999).

Results

The results of learning device development using Thiagarajan or 4-D model are described as follows.

Define Stage

Based on the results of learning devices observations at State Senior High School 2 Binjai, it was found that there were several weaknesses in the learning device used by the teacher which indirectly contributed to the low metacognition abilities of students. The learning device used by teachers and students produce teacher-centered learning so that students are not active in learning. The learning model used is still in routine activities for all materials such as lectures and assignments. The lesson plan is also not conditioned on the needs or characteristics of students. The student text books that been used in mathematics learning are not designed by the teacher so that they cannot reach the special needs and characteristics of students. In addition, student worksheets have not been used in the class, which causes students to be less trained in developing their mathematical skills. The teacher designs evaluation tools without paying attention to the indicators of ability to be achieved. These are the causes of student metacognition ability to be low.

Design Stage

At this stage, an initial draft of the lesson plan was produced for 3 meetings, student text books, teacher guide books and student worksheets, and metacognition ability tests. All results at this design stage are called draft-I. All devices designed are adapted to problem-based learning models and their application is expected to have an impact on increasing students' metacognition ability.

Develop Stage

After the learning device that uses problem-based learning is designed in draft I, validity tests are conducted on experts and field trials. The goal is to correct mistakes and weaknesses in the draft results (draft I) which are then used as a basis for revising and perfecting the learning device. The revised test from expert teams were then tested on third year students of State Senior High School 2 Binjai.

After the learning device developed met the validity criteria (draft II), the learning device in the form of draft II was tested at the research location, furthermore referred to as Trial I. Trial I was carried out in second year of PMS 2 class at State Senior High School 2 Binjai. Trial I was conducted to measure the practicality and effectiveness of the learning device (draft II) which was developed through a problem-based learning model which aims to improve students' metacognition skill.

Overall, the results of the data analysis of the first trial of the developed devices did not meet the practical and effective criteria. Based on the results of the analysis and trial I, it is necessary to revise some of the components of the learning device developed. The results of the first trial are used as a reference for improving the learning device. The revision results in the first trial resulted in draft III which would be tested on second year of PMS 3 class at State Senior High School 2 Binjai. Trial II was conducted to re-measure the practicality and effectiveness of the learning device (draft III) which was developed through a problem-based learning model which aims to improve students' mathematical critical thinking skills. Overall the results of the data analysis of trial II or it is known that the results of trial II are better than trial I.

Disseminate Stage

The disseminate stage is a final stage of development. The disseminate stage is carried out to promote the development product to be accepted by users, whether individuals, a group, or a system.

Several things that need attention in carrying out the distribution are: (a) User analysis is the first step in the disseminate stage to find out or determine the users of the product that has been developed; (b) Determination of disseminate strategies and themes is a design for achieving product acceptance by prospective users of development products; (c) Determination of this time is very important, especially for product users in determining whether the product will be used or not (reject it); and (d) The selection of media for dissemination can be in the form of educational journals, educational magazines, conferences, meetings, and agreements of various kinds as well as through e-mail transmission (Thiagarajan et al., 1974). The dissemination stage in this research was carried out by providing problem-based development products to mathematics teachers of second year State Senior High School 2 Binjai in the form of flash drives after classroom research and publishing research results in the form of international journals.

Quality of Learning Devices Development

The result of validation on lesson plan is 4.26, students text book is 4.24, teacher guide book 4.24 and students worksheet is 4.26. It has valid category based on the level of validity. The reliability of metacognition ability test was 0.85 (high category), so the test is considered to be good to used. Then, it can be concluded the problem-based learning devices is valid.

Based on the implementation result of problem-based learning device from first trial is 81.67 and second trial is 87.67. It is considered well. So, it can be concluded the problem-based learning devices is practical.

The effectiveness of the learning device is seen in two aspects, namely the classical completeness results and the results of student responses. The results of classical completeness of students' metacognition abilities are shown in the Table 1.

Table 1. Results of Classical Completion of Students' Metacognition Abilities

Category	Total students		Percentage	
	Trial I	Trial II	Trial I	Trial II
Completed	26	30	72,22%	85,71%
Not complete	10	5	27,78%	14,29%
Total	36	35	100%	100%

Based on the classical completeness table, the students' metacognition ability was achieved in the second trial, namely at least 85% of students obtained a minimum value of B^{-}. Meanwhile, the results obtained from student responses response is 87.25%. It is considered students mark positive perception to and response towards the problem-based learning device. It can be concluded that the results of classical completeness of students' metacognition abilities and student responses to components and learning activities based on problem-based learning have met the criteria of being effective, or problem-based learning devices is effective.

The Improvement of Students' Metacognition Ability

Based on the data obtained from the pre-test and post-test of students metacognition abilities in trial I and trial II, it showed an improvement in students' metacognition abilities by using normalized gain score. The result of n-gain trial I showed that 4 students in the high criteria, 22 students in the medium criteria, and 10 students in the low criteria. The result of n-gain trial II showed that 10 students in the high criteria, 22 students in the medium criteria, and 3 students in the low criteria. Based on the results, it can be seen that the highest percentage is in the medium n-gain criteria. It is shows that there is a medium

increase in the results of the pretest and posttest. So, in the learning process using problem-based learning device can improve students' metacognition abilities in the medium category.

Discussion

Metacognition abilities can increase because the devices applied to students meet the criteria for good quality learning device, with the good learning device used and with the application of problem-based learning, the students' metacognition abilities increase (Halimatussadiah et al., 2018; Siagian et al., 2020). This is in line with Paidi's (2011) research which states that there is a significant effect of implementing problem-based learning device on students' metacognition abilities.

The results of the development of problem-based learning device are supported by learning theory. Piaget's learning theory states that new knowledge is not given to students in a finished form but students build and develop their own knowledge from the results of their interactions with their environment. In addition, social constructivism or vygotsky's learning theory states that knowledge cannot be transferred from other people's thoughts to one's thoughts, but that person must build their own knowledge through interactions with other people. Another important thing from Vygotsky's learning theory is scaffolding, which is the necessary assistance provided by the teacher to students which is then gradually reduced, finally students can stand alone in carrying out learning activities. Another learning theory is Bruner's theory of learning about the propositions of discovery and the proposition of association. The discovery method is indeed a concept that underlies problem-based learning because in problem-based learning students are given problems to find ways to solve them by students and their findings are knowledge related to the knowledge of the material to be taught. Linking theorem also underlies problem-based learning because in this learning every concept is related to other concepts.

Conclusions

Product development of problem-based learning device to improve metacognition abilities has been declared valid, based on the results of validation by experts that the learning device is in the valid category. Declared practical, based the implementation of learning device is in a good category. Declared effective, based on fulfilled classical completeness criteria and positive student responses to the learning device developed. There is an improvement in students' metacognition ability based on n-gain in the medium category.

Problem-based learning device can be used as an alternative to improve students' metacognition abilities and the result of this research can be used as information for the next researcher.

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