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Effectiveness of Mathematics Modules Based on Problem-Based Learning to Improve Students' Reasoning Ability in Junior High School

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Abstract

This study aims to determine the effectiveness of mathematics modules based on problem-based learning to improve the reasoning ability of eighth grade students at Junior High School (SMPN) 2 Jumapolo. Reasoning ability is one of the goals of mathematics education, the problem is that the reasoning ability of eighth grade students in Indonesia, including at SMPN 2 Jumapolo, is still relatively low. The development of mathematics modules based on problem-based learning is expected to be a solution to overcome these problems. In this study, the mathematics module based on problem-based learning was tested on thirty eighth grade students at SMPN 2 Jumapolo. This research is quasi-experimental research with One Group Pretest Posttest Design. Samples were taken by cluster random sampling. Students are given a pretest to determine the students' initial reasoning ability. The students were given treatment in the form of learning by using a mathematics module based on problem-based learning. After that, students were given a post-test to measure the students' final reasoning ability. The data collection technique used in this study was a test of reasoning ability. The data analysis technique used was the paired t-test. Based on the results of the paired t-test, it was found that the students' final reasoning ability was better than students' initial reasoning ability. The students' reasoning ability increased by 52.80 percent. This shows that the mathematics module based on problem-based learning was effective in improving the reasoning ability of grade eight students.

Keywords: *effectiveness, mathematics module, problem-based learning, reasoning ability*

Introduction

As we all know, education is an important part of life. Through education, humans are prepared to face difficulties and challenges in life. Education is essentially an effort to prepare students to face an increasingly rapidly changing life environment; besides that, education is a tool in applying the principles of science and technology for the formation of a complete human being (Widyasari et al., 2015). Currently the world is entering the era of the fourth-generation industrial revolution and progress is occurring in almost all fields, especially in the fields of technology and science which provide greater convenience and challenges. The current generation needs to have various abilities and skills, including basic skills, technology skills, problem-solving skills, communication skills, critical and creative skills, information/digital skills, reasoning skills, interpersonal skills, and multicultural and multilingual skills.

One of the skills needed to be able to face challenges in the 4.0 revolution era is the ability to reason. Logic, and critical and creative thinking in the form of problem solving are high-level abilities and competencies needed to survive (Napitupulu, 2016). Reasoning is defined as the line of thought adopted to produce a statement and reach a conclusion when completing a task. Reasoning can be seen as a thinking process, a product of a thinking process, or both (Bergqvist & Lithner, 2012). Reasoning is very effective for students' ability to analyze new situations encountered in all aspects; explain their thinking, make logical assumptions, draw conclusions and defend their conclusions (Arslan et al., 2009).

Mathematics learning provides logical, systematic, critical and careful reasoning ability as well as objective and open thinking which are indispensable in everyday life to face an ever-changing future (Tandilling, 2012). Mathematics is one of the important subjects taught in schools. It is necessary to transfer mathematical knowledge and skills acquired in school to real life (Svecova et al., 2014). The benefits of mathematics applied by students are to support and develop other subjects such as science, physics and economics, and can be used by students to socialize in everyday life (Astuty et al., 2019).

Reasoning ability is one of the five ability standards that students must have in learning mathematics. Reasoning is an essential component of mathematical ability (Bernard & Rohaeti, 2016; NCTM, 2000). Mathematics and reasoning are two interrelated things, mathematical material can be understood by reasoning and reasoning can be honed from learning mathematics (Nurfadhilah & Amir, 2018). Reasoning can be used in understanding mathematical concepts and doing math well and is an integral part of problem solving (Kartono & Shora 2020; Basir, 2015). Mathematics can develop skills that involve the ability to reason logically, carefully,

systematically, critically and creatively in conveying ideas and solving problems (Misnasanti et al, 2017; NCTM, 2000).

Mathematics is one of the fields studied by students (Telaumbanua, et al., 2017). The world provides many opportunities for generating mathematical tasks. Mathematics is a part of many daily activities and of many work situations. Mathematics courses consist of various interrelated topics and concepts (Malasari et al., 2017). Mathematics, in addition to containing arithmetic material, also involves true or false statements, compiling evidence, and making conclusions from a statement that requires reasoning ability. Ball and Bass (Brodie, 2010) state that reasoning is a basic mathematical ability and is important for various purposes such as understanding mathematical concepts, using mathematical ideas and procedures flexibly and rebuilding existing knowledge.

Students should enter middle grade with the notion that mathematics is involved in checking patterns and noting regularities, making conjectures about possible generalizations and evaluating these conjectures (NCTM, 2000). Reasoning ability is an important aspect for students in solving mathematical problems. Therefore, having the ability to reason is one of the goals in learning mathematics. This shows that reasoning ability is an important part of mathematics and reasoning is an essential ability and need possessed by junior high school students in learning mathematics. Indicators to identify students' reasoning ability in this study were making conjectures, drawing conclusions, checking the validity of arguments, and making generalizations.

Based on the results of the Programme for International Student Assessment (PISA) in mathematics for class VIII in 2018, Indonesia was ranked in the bottom six out of 78 countries. According to the 2015 Trend in International Mathematics and Science Study (TIMSS) for eighth grade, Indonesia is ranked 45th out of 50 countries. According to Murtiyasa (2015) the results of the PISA and TIMSS studies essentially indicate the strength of students' reasoning and the ability to apply this in everyday life. Therefore, the results of PISA and TIMSS show that the reasoning ability of junior high school students in Indonesia is in the low category, including the class of eighth grade students of SMPN 2 Jumapolo.

Based on the initial test given to the class of eighth grade students of SMPN 2 Jumapolo, it is known that there were many students who were not able to solve math problems related to indicators of reasoning ability such as making generalizations, drawing conclusions and making assumptions. This shows that most students master mathematical formulas but have not mastered reasoning skills. Based on observations made at SMPN 2 Jumapolo and interviews with mathematics teachers, information was obtained about students' difficulties in learning mathematics and the students' ability to solve math problems was still low.

Teachers tend to continue to use learning strategies that lead to teacher-centered learning so that the class of eighth grade students are still learning with a system of paying attention and recording teacher explanations. As a result, students are less active in the mathematics learning process and still rely on formulas and examples of questions that are given.

The learning components that are the determining factors and driving factors in learning activities include teaching materials, learning media, evaluation instruments and learning implementation plans. One of the factors that affect students' low mathematics learning outcomes can be sourced from student handbooks that do not involve application, reasoning, critical thinking and problem solving and the lack of scientific context (Murtiyasa et al., 2016).

Based on the results of interviews with mathematics teachers and observations about teaching materials at SMPN 2 Jumapolo, in the implementation of mathematics learning the teacher used mathematics textbooks and workbook , which emphasized material and practice questions but did not use everyday problems around students. The mathematics textbooks and workbook used in schools already use the 2013 curriculum, but have not motivated students to learn independently and have not been able to improve students' reasoning abilities.

Based on the results of the needs analysis questionnaire given to students, it was found that only about ten percent of students had handbooks other than those given by the school, especially on circle material. Seventy-five percent of students still have difficulty learning the material in the handbook provided by the school. Seventy-five percent of students have difficulty understanding circle material partly due to limited learning resources, teaching materials and methods used by teachers.

The teaching materials used in the learning process are textbooks and student worksheets, but these teaching materials make students less active in participating in the learning process. The teaching materials are used only as a tool to provide materials and exercises or assignments and have not been able to instill interest in learning mathematics in depth, so students still have difficulties in learning mathematics. It takes teaching materials that can help students receive the material more easily and make students able to play an active role in the process of learning mathematics. The use of appropriate teaching materials can help students develop their reasoning ability. One type of teaching material that can be developed and used to improve students' reasoning ability is a module. Learning mathematics using modules will be beneficial for teachers and students because students can learn more directly and systematically (Purwanto et al., 2007).

In addition to teaching materials, reasoning ability can be developed through problem-based learning (PBL) by guiding students to solve mathematics problems related to everyday life. Problem-based learning is one of the learning methods that

can provide conditions in which students are required to be active in learning activities. According to Boud and Faletti, problem-based learning is based on the belief that learning is more effective when students are actively involved and learn in contexts where general knowledge is used (Huijser et al., 2015). The problem-based learning model is a teaching method that starts with a problem and stimulates students to learn through examining real problems (Ari, 2014; Bidokht & Assareh, 2011).

Duch (Sumartini, 2015) defines problem-based learning as a learning approach that has the characteristics of using real problems as a context for students to learn critical thinking and problem-solving skills, and gain knowledge about the essence of learning materials. In learning activities, students not only record and memorize material, but students actively think in solving real problems. Problem-based learning methods are more successful in improving students' reasoning ability than textual discussion methods (Ruhimat et al., 2017).

This problem-based learning model can be used as the basis for teaching materials, namely modules based on problem solving. The selection of the right learning media in the form of learning modules that contain the concept of problem-based learning can attract students' interest and attention in learning mathematics. According to Lasmiyati and Harta (2014), the module approach provides feedback so that students can find out their shortcomings and immediately fix them; student performance is more focused on achieving learning goals; the module is designed to be attractive, easy to learn, and generates student motivation; and the module has a flexible nature in that material in the module can be learned by students in different ways and speeds. Through the use of modules, students are given the opportunity to build their own knowledge and are directed to focus their attention on problems and look for alternative problem solving both individually and in groups; thus the module will be effective if it is combined with problem-based. learning (Setyadi & Saefudin, 2019).

The application of learning modules is considered an appropriate and effective method to reactivate student learning activities and develop students' ability independently. The problem-based learning model phase is perceived as the right alternative to integrate each learning activity from the module. Problem-based learning looks like a promising learning model because the learning model can facilitate students in appreciating their reasoning ability. Mathematics modules based on problem-based learning are teaching materials used in mathematics learning whose contents are relatively short and specific, which are systematically arranged and integrated with the syntax of problem-based learning and interesting learning models to achieve certain goals that can be used independently. The stages in the syntax of the problem-based learning model in this study consisted of 1)

problem orientation, which explains learning objectives, explains the logistics needed, and motivates students to be involved in problem-solving activities, 2) organizing students for learning, which helps students define and organize learning tasks related to the problem, 3) individual guiding/group experiences, which encourage students to collect appropriate information and carry out experiments to get explanations and solve the problem, 4) developing and presenting the work, which helps students in planning and preparing appropriate work such as reports, and helps them to share assignments with their friends , and 5) analyzing and evaluating the problem-solving process, which helps students to reflect on or evaluate their investigations and the processes they use (Sumartini, 2015). Each stage in the problem-based learning model syntax that is applied to the module makes a contribution to improve students' reasoning ability.

The module to be developed is oriented towards a learning model; namely, the problem-based learning model. The problem-based learning model is characterized by using real problems as a context for students to develop thinking skills, develop independence and confidence in solving problems and to acquire their own knowledge. The advantages of problem-based learning are that students learn to think critically, acquire problem-solving skills, gain knowledge about the essence of learning materials, and actively think, communicate, search for and process data, and make conclusions. According to Hmelo-Silver (2004), the problem-based learning model helps students: (1) understand information; (2) improve problem-solving ability; (3) acquire lifelong learning and individual learning skills; (4) promote fruitful collaboration; and (5) increase intrinsic motivation in learning and become a productive individual.

Mathematics modules based on problem-based learning can help students improve their reasoning skills through problem-solving activities in the module systematically so that students' reasoning ability increase (Markus, 2018). This is in line with the research by Handayani and Mandasari (2018) which produces student worksheets based on problem-based learning which have the potential to affect the improvement of students' reasoning ability. The modules are designed to be systematic and attractive to students. The mathematics module developed based on problem-based learning in this study has met the valid criteria based on the validator's assessment and meets the practical criteria based on the assessment of students and teachers as module users.

The mathematics module in this study contains mathematical material on the subject of circles for eighth grade students of junior high school. The mathematics module based on problem-based learning is expected to be able to make students active in the learning process and make it easier for students to understand mathematical material so that students' reasoning abilities are

expected to increase. Based on these problems and potentials, a study was conducted to determine the effectiveness of a mathematics module based on problem-based learning to improve the reasoning ability of eighth grade students in junior high school.

Method

This research is part of research and development research at the field trial stage to see the effectiveness of the module after it has been developed and validated by experts. This research stage uses quasi-experimental research.

Research Design

This research was conducted at SMPN 2 Jumapolo. The research was carried out in February 2020. The research design was One Group Pretest-Posttest Design. According to Budiyono (2017) in the One Group Pretest-Posttest Design, only one group of subjects is used. First the measurement is carried out as an initial test (pretest) then subjected to certain treatment and within a certain period of time, then measurements are taken as a final test (post-test). In this study, this design was used to see the difference in the results of students' reasoning ability before and after being given treatment; namely, learning mathematics using a mathematics module based on problem-based learning.

Sample

The mathematics module based on problem-based learning was piloted in one class, the eighth-grade students of a junior high school. Class determination used cluster random sampling. In this study, the sample used was thirty people. For field trials, according to Purwanto et al. (2007), a sample of twenty to thirty people is required. First, the subjects were given a pretest, then subjected to treatment in the form of learning by using the mathematics module based on problem-based learning. After that measurements were taken by giving a post-test.

The data collection technique used in this study was a test of reasoning ability. The research instrument used is a question of reasoning in the form of a description, syllabus and lesson plans. The reasoning ability question instrument before being given to the sample class had been tested to determine the validity, reliability, discriminatory power, and level of difficulty of the questions. The indicators used to measure students' reasoning ability in this study were 1) proposing conjectures, 2) performing mathematical manipulations, 3) drawing conclusions, 4) checking the validity of an argument, and 5) making generalizations.

The data analysis technique used to answer the hypothesis in this study was to use the paired t-test. Before carrying out the t-test on the data resulting from

reasoning ability, first the normality test was carried out using the Liliefors test, and the homogeneity test using the Barlett test, to show that the sample came from normal data and the research sample came from a homogeneous population.

The pretest and post-test will be analyzed, and it aims to test the hypothesis. The hypothesis is:

H_0 : The reasoning ability of students after using the mathematics module based on problem-based learning was no better than the reasoning ability of students before using the mathematics module based on problem-based learning.

H_1 : The reasoning ability of students after using the mathematics module based on problem-based learning was better than the reasoning ability of students before using the mathematics module based on problem-based learning.

Results and Discussion

Effectiveness basically questions whether the product developed has met the objectives or not. Learning tools are said to be effective if the learning objectives can be achieved through the use of developed learning tools (Nieveen, 1999). The effectiveness, or not, of a product, method or learning model can be seen by an increase or change in a better direction of motivation, learning outcomes, behavior and so forth (Febriana et al., 2017). This paper will show the effectiveness of the product in the form of a mathematics module based on problem-based learning, for circle material in grade VIII in SMPN 2 Jumapolo. The effectiveness of the module based on problem-based learning is seen from the results of the reasoning ability test consisting of pretest and post-test. The values obtained from the results of the pretest and post-test were analyzed using a paired data t-test.

Table 1. *Reasoning Ability Summary with Paired Sample T-Test*

	Paired Differences					t	df	Sig (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of The Difference				
				Lower	Upper			
Posttest-Pretest	5.167	4.043	0.738	3.656	6.676	6.998	29	0.00

Reasoning ability scores are analyzed through pretest and post-test result data. The pretest and post-test score data are presented in Table 1 showing average score and standard deviation after the data processing of reasoning ability tests. The pretest and post-test consist of six items with each question having a maximum score of 4. So that the maximum score that students will get if they do all the items correctly is 24.

The pretest and post-test value data were analyzed by the Paired Sample t-test (paired two-sample t-test). Based on the calculation, t_{count} = 6.998 and significance level p = 0.000 (p < 0.05), then the null hypothesis is rejected. The results of the paired data t-test analysis showed that the reasoning ability of students after learning using a problem-based learning mathematics module was better than the reasoning ability of students before learning using a mathematics modules based on problem-based learning. This means that the mathematics module based on problem-based learning is effective in improving students' reasoning ability. This is in line with the results of research from Akbarita and Narendra (2019), Handayani and Mandasari (2018), and Nurhidayati, Tayeb, and Baharuddin (2017); namely, the development of mathematics modules based on problem-based learning can help improve students' reasoning ability.

Table 2. *Comparisons of Students' Reasoning Ability Before and After the Experiment*

		Before The Experiment		After The Experiment	
Reasoning Ability	N	Mean	S	Mean	S
	30	11.23	5.79	17.16	12.48

From Table 2, in the pretest (before the experiment) students' reasoning ability has an average 11.23. Then students were given treatment in the form of learning by using a mathematics module based on problem-based learning. After that students were given a post-test. Based on the table above, the post-test (after the experiment) average of students' reasoning ability is 17.16. This shows that there is an increase in reasoning ability after using mathematics modules based on problem-based learning. An average increase of 5.93 points or 52.80 percent occurred. The data from Table 2 indicates that the module has been developed effectively to improve students' reasoning ability. This is also supported by research conducted by Za'ba and Prabawanto (2019) which concluded that after having learned with problem-based learning modules the students highly understood and mastered mathematical reasoning.

Students' reasoning ability increases because learning activities in modules require students' ability to find concepts from the material. Students follow each

learning activity on the module and start to be curious with the module. The curiosity happens because every learning activity in the module starts with real problems that guide students to find out the concept materials. If students find difficulties or doubts in solving problems contained in the module, students can ask questions or ask opinions from the teacher or other students in the group.

Each phase in the problem-based learning syntax that is applied to the module makes a contribution to improve students' reasoning ability. The first phase in problem-based learning syntax is in the "let's guess" stage which develops students' reasoning ability, especially on indicators of making conjectures/predictions. In this first phase, students observe the problem and guess the answers and how to solve the problems presented in the module. The second phase in the problem-based learning syntax is in the "let's discuss" stage. In this phase students are asked to form groups for discussion. The third phase in problem-based learning syntax is at the "let's analyze" stage. At this stage, students are trained to develop their reasoning ability, especially on indicators of performing mathematical manipulations and making generalizations when looking for information to solve the problems given in the first phase. Students solve problems by exploring knowledge, conducting experiments, and connecting previously learned concepts to find new concepts through problem solving.

The fourth phase in problem-based learning syntax is at the "let's make a presentation" stage. At this stage, students are trained to develop reasoning skills on indicators to check the validity of an argument. At this stage, students write down the results of their problem solving and present the results of discussions with their groups. The last phase in the mathematics module based on problem-based learning syntax is at the "let's make conclusions" stage. At this stage, students are trained to make conclusions from the results of discussions and presentations. The reasoning ability developed is on the indicator of making conclusions. At this last stage, students use the results to draw conclusions from the results of problem solving and the processes used in solving problems.

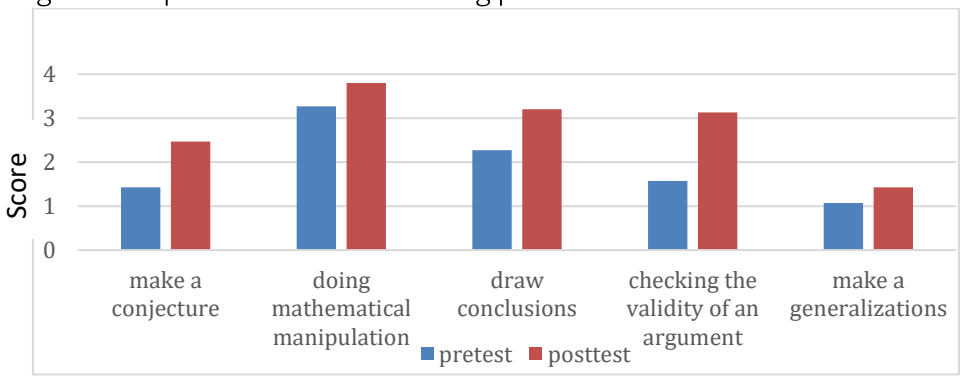

Figure 1. *Average Chart Per Indicator*

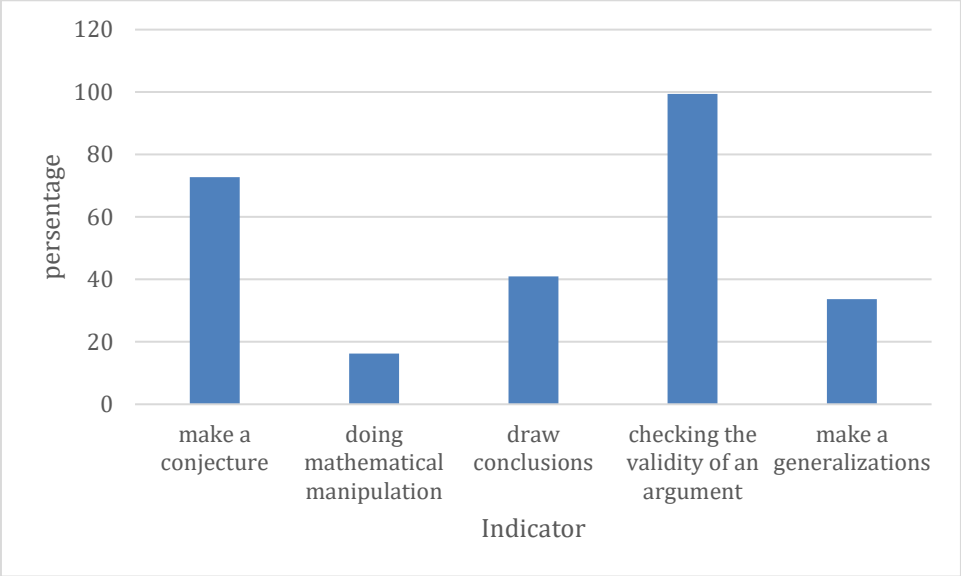

Figure 2. *Increasing Indicator Reasoning Ability*

From Figure 1, it can be seen that the average reasoning ability indicator has increased after using the problem-based learning mathematics module. From Figure 2, it is known that the indicators that experienced a significant increase were making assumptions and checking the validity of the arguments. From these indicators, most of the students were able to give systematic answers. A rapidly improving indicator is checking the validity of the argument. This is because there are presentation activities in the module, namely at the "let's make a presentation" stage. When students from the selected group make a presentation, students from other groups will respond and check whether the answers/arguments given by the presentation group are true or false.

The indicator on making predictions also increased. Each learning activity in the module begins with a real problem that must be solved by students. When students read the questions, students will practice their ability to make projections, students will guess the answers and/or how to solve the problem. The indicator for drawing conclusions also experienced a fairly high increase. Students' ability to draw conclusions is trained in the "let's conclude" section contained in each learning activity in the mathematics modules based on problem-based learning. In this section, students are invited to draw conclusions from the problems and material studied in each learning activity.

The indicator of makes generalizations increases but is not high enough. This is due to the lack of training in modules that use or train the ability to make generalizations, so that students are less trained in making generalizations. Students still have difficulty in making generalizations because most students are

still focused on substituting numbers into formulas and have not been able to see the pattern of the questions asked. The indicator of mathematical manipulation increased only slightly, this is because at the pretest the students were quite good at performing mathematical manipulations, so that the students' scores on the post-test increased not significantly compared to the pretest. Based on Figure 1 and Figure 2, it can be seen that the students' reasoning ability in each indicator increases. That is, learning by using modules makes students better understand the concepts of the material provided and students are more active.

In the process of learning mathematics, there are several learning components that affect the achievement of learning objectives, one of which is teaching materials (Telaumbanua, et al., 2017). The use of modules can condition learning activities to be more well-planned, independent, complete, and with clear results (Widyasari et al., 2015). The use of modules in the learning process supports the teacher's role as a facilitator because students must be active to find concepts from the learning material by following the steps of PBL contained in the module (Sari, et al. 2018). Learning using mathematics modules based on problem-based learning helps students to understand and find material concepts. This module is one of the teaching materials that helps students understand the learning material. Teaching materials assist students in learning and assist teachers in increasing the effectiveness of learning to achieve certain competencies.

Based on the results of the study, it can be seen that the use of problem-based learning mathematics modules is effective in improving students' reasoning ability. This is supported by research by Palobo and Nur'aini (2018) who investigated learning tools based on problem-based learning and oriented to reasoning ability. The results of their research show that the percentage of students who complete the reasoning ability test reaches 82.76 percent. This shows that learning tools in the form of modules, syllabus, and lesson plans based on problem-based learning improve students' reasoning ability. According to Za'ba and Prabawanto (2019), modules based on problem-based learning can attract students' interest and are easy to use in the learning process so that students really understand and master reasoning ability. Likewise, Handayani and Mandasari (2018) in their research found student worksheets based on problem-based learning for junior high school students have a potential effect on increasing students' mathematical reasoning ability.

According to Ruhimat (2017), problem-based learning has succeeded in improving students' reasoning ability. The application of problem-based learning in the classroom facilitates students achieving higher-order thinking skills to be a natural choice, especially in junior high and high school (Napitupulu, 2016). Problem-based learning methods teach starting with problems (Ari & Katranci,

2014) and stimulate students to learn through real problems (Bidokht & Assareh, 2011). Problem-based learning aims to develop students' higher thinking patterns, and helps them think critically and be able to solve the problems presented (Siagian et al., 2019). Problem-based learning improves students' thinking skills and provides permanent learning (Ari & Katranci, 2014). Wulandari dan Syofiyah (2018) in their research showed that problem-based learning can effectively facilitate students' reasoning.

The mathematics module based on problem-based learning in this research has several advantages, namely: 1) it provides new insights and knowledge to students through the link between the circle material and the problems of everyday life: 2) it contains circle material which is arranged based on the steps of the problem-based learning model, and modified by adding an indicator of reasoning ability that is integrated with the problem-based learning model with the aim of improving students' reasoning ability; and 3) it received a positive response from students in terms of appearance, language used, and module content so as to encourage students to study independently. The drawback of this mathematics module based on problem-based learning is that this module is limited to circle material for class VIII students.

Conclusion

Based on the conducted research we can conclude that the reasoning ability of students after learning by using mathematics modules based on problem-based learning increases by 52.80 percent. The effectiveness of the module is seen from the increase in students' reasoning abilities which is calculated by the paired data t-test. The results of the effectiveness test on the problem-based learning mathematics module trial were obtained from $t_{obs} = 9{,}43$ where DK = $t > 1{,}69$ because of $t_{obs} \in DK$, then H_0 is rejected. The final conclusion of the effectiveness test, the PBL-based mathematics module was declared effective for use in learning mathematics to improve reasoning abilities.

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