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Increasing Senior High School Students' Mathematical Problem-Solving Ability and Mathematical Disposition Through Problem-Based Learning Assisted by Simple Mathematics Kit

Achmad Mudrikah

Universitas Islam Nusantara,Bandung, Jawa Barat, Indonesia; achmadmudrikah@yahoo.co.id

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ABSTRACT

This research intends to reveal the increasing number of senior high school students' mathematics problem-solving ability and mathematical disposition. The study involved 124 private secondary school students consisting of two types of school: ordinary private schools and private schools managed by Islamic boarding schools. In addition to examining the mathematical problem-solving ability and mathematical dispositions of students based on the type of school and type of learning, this research is also researched based on the students' prior mathematical abilities. This experimental study involved 124 students as the research sample. To obtain the data, pre-test and post-test were conducted. Meanwhile, to analyze the data, the researcher implemented two-way ANOVA. The results showed that the mathematical problem-solving ability and mathematical dispositions of students who used problem-based learning assisted by simple mathematics kit was better than students who only received problem-based learning. Students from Islamic boarding schools can show better problem-solving ability when studying mathematics with problem-based learning assisted by simple math kits. Students from Islamic boarding private school gain better problem-solving abilities than students from a non-boarding private school, especially students who have high and medium prior mathematical abilities.

Corresponding Author:
Achmad Mudrikah
Universitas Islam Nusantara, Bandung, Jawa Barat, Indonesia; achmadmudrikah@yahoo.co.id

1. INTRODUCTION

Students' mathematical problem-solving abilities as one of the high-order mathematical thinking abilities have always been one of the objectives of mathematics learning given by mathematics teachers in schools. Problems in mathematics are interpreted as a situation when someone cannot answer a question or test in the way that is usually done (Siagian, et al., 2019). Meanwhile, mathematical problem-solving ability, according to Priya (2017) is the ability of the students to read the problem carefully, analyze the information, and examine the appropriate strategy that will help to find a solution. Thus, a student who has the mathematical problem-solving ability is a student who has a high order mathematical thinking ability because he can overcome non-routine problems that are faced when learning mathematics.

Besides paying attention to the cognitive aspects of the learning process, students studying mathematics must also pay attention to their attitudes towards mathematics. Oftentimes it is found that students already have a scholarly attitude towards mathematics. According to Nugroho et al. (2018), scepticism in students can occur due to two reasons: (1) the existence of cognitive conflict and (2) the existence of two conflict outcomes. Of course, this sectional attitude must be considered and made as a special matter that must be corrected by improving students' mathematical dispositions. Mathematical disposition, according to Almerino et al. (2019) is a confident attitude that is formed by perceptions, values, emotions and behaviour towards subjects, in this case towards mathematics. To form a belief in mathematics requires special attention besides attention to the formation of cognitive abilities from mathematics itself. Kusmaryono (2019) states that the attitudes and attention of teachers towards students' mathematical dispositions are important factors that can influence students' mathematical dispositions as well as assess the effectiveness and quality of mathematics teachers. Thus, teachers must be able to create learning that can be responded to well by students. A good response from students in learning will be seen from the activeness of the students. Meanwhile, the activity of students in the classroom can be seen from the high motivation to learn, activities in group discussions, and activities to ask the teacher.

Various learning methods have been applied by mathematics education teachers and researchers in an effort to achieve the goal of increasing high-order mathematical thinking ability in the form of mathematical problem-solving ability and mathematical disposition. Teaching students high-order mathematical thinking ability requires preparation from the teacher and careful planning. The teacher's preparation and planning must be directed at overcoming the difficulties that are often faced by students. The difficulties that students often face in increasing their mathematical problem-solving ability include their lack of initial knowledge regarding the problem to be solved (Mukasyaf et al., 2019). In fact, the ability to solve math problems requires at least 3 phases in students in the form of students understanding the problem, making a solution plan using initial knowledge and working on the problems and evaluating them (Mukasyaf et al., 2019). Indicators of problem-solving abilities that should be present in students often cannot be displayed when students work on questions. Students tend not to have the ability to identify elements that are actually known in the problem, and also what is being asked. Students are also unable to formulate mathematical problems or develop a mathematical model from the problems given (Surya et al., 2017).

Son et al. (2020) stated that the interaction between learning models and types of cognitive abilities impacts students who have mathematical problem-solving abilities, strengthening the opinion about the importance of teacher preparation. The teacher must make the right learning approach through the correct steps in an effort to improve students' mathematical problem-solving abilities. The learning approach in question must also be able to be followed by students and even be able to please students. Simamora et al. (2019) stated that joyful learning could help students discover mathematical concepts independently with the atmosphere that students like. Osman, et al (2018) stated that teachers must use a variety of methodologies and strategies to teach problem-solving. Students cannot solve problems well if they do not have a variety of problem-solving skills.

Research on learning that is pursued in order to improve problem-solving abilities has also been carried out. Castro, et al. (2018) promote leisure activities so that students develop creative intelligence in the form of imagination to facilitate mathematical problem-solving. Demitra & Sarjoko (2018) suggest that the cooperative learning model is more effective for learning mathematical problem-solving because the model constructs integrated components of handed mutual cooperation steps, mathematical problem-solving step, and metacognition questioning strategy. Birisci (2017) investigated the impact of incorporating synchronous online and face-to-face collaborative group studies on the attitude of mathematical problem solving. His research found that learning in a synchronous online, face-to-face collaborative group study enables students to overcome problem-solving steps more systematically with the help of multiple ideas within group members. Steyn & Adendorff (2020), through their research stated that effective questioning practice for teaching mathematical problem-solving must be explicitly taught to foundation phase education students as part of the curriculum. All

of the above research is part of various studies which emphasize that well-prepared learning can have a positive impact on improving students' problem-solving abilities in various aspects that are the objectives of the research.

The disposition, according to Seel (2012) is a general, relatively stable inclination to approach new learning tasks and situations in a particular way. Regarding dispositions towards learning in general, Crick & Goldspink (2014) stated that research on learning dispositions develops from its origin in the form of attention to learning into an effort to overcome the need for deep involvement in learning and a pedagogical approach that allows students and teachers to focus on improving the process. learning, allows individuals to reflect on approaches to learning, and has students begin to control their own path through the curriculum rather than relying on teacher direction. Meanwhile Cooke (2015) states that there are four elements that can be used as a measuring tool for mathematical disposition, namely: 1) attitude towards mathematics, 2) mathematics anxiety, 3) confidence in mathematics, and 4) how mathematics is conceptualized. With the understanding of the mathematical disposition mentioned above, it can be concluded that the preparation of mathematics learning by the teacher must also pay attention to the mathematical disposition of students as one of the learning objectives.

Research on learning that is attempted to improve mathematical disposition has been carried out by Dina et al. (2019), Yaniawati, et al. (2019), Sari & Darhim (2020), and Graven (2012). Dina et al. (2019) found that discovery learning models can improve students' mathematical disposition more than conventional learning. Sari & Darhim (2020) which applies Relating, Experiencing, Applying, Cooperating, and Transfering (REACT) strategy as an implementation of a contextual learning approach can be applied to develop students' mathematical representation, reasoning and mathematical disposition ability. The strategy that runs smoothly and gets enthusiastic responses from students, makes students more excited when learning, especially when the teacher asks students to present the results of their group work in front of the class. Graven (2012), revealed through the results of his research that related to students' mathematical dispositions, there must be a change in the mathematics learning culture that relies on teachers passively. Graven (2012) also wants to interrupt notions that mathematics learning must be teacher led or initiated by a clear teacher method or instruction. In addition to paying attention to aspects of understanding, mathematics learning must also pay attention to personal development and student participation in learning. As for Yaniawati et al. (2019) stated that students' mathematical disposition arises when the students had completed the mathematics task carried out with confidence, responsibility, and diligence, never give up, feel challenged, have the willingness to look for other ways and reflect on the ways of thinking that has been done. The CORE learning model developed by Yaniawati, et al (2019) has resulted in students' mathematical disposition abilities that are better than students who have learned the expository model. The overall research above has shown that well-prepared learning in the sense that by paying attention to various supporting aspects of the abilities that the teacher wants to aim at, can have an effect on improving students' mathematical dispositions.

Problem-based learning, according to Amin et al. (2020), Maskur et al. (2020), Ceker and Ozdamli (2016), Suprapto, et al. (2017), and Thakur et al. (2018), can improve various skills in students such as high order thinking skills, creative thinking skills, reasoning skills, decision-making skills, scientific skills, communication skills, self-regulated learning skills, problem-solving skills, team skills, and leadership skills. This happens because problem-based learning as one of the promising innovative technologies for the educational process (Abushkin, 2018), can require students to think creatively to find solutions to problems, direct students to take the information that has been collected within them as individuals and in groups while solving problems, make students think using scientific stages in solving problems, demanding students communicate with each other in groups when conducting discussions, demand the remainder to think and learn independently, students are presented with real problems, demand students collaborate in groups, and demand that students have leaders in their study groups. The various skills that can be improved by problem-based learning above can of course be more focused with an emphasis on the focus of the targeted skills both in the learning process and

through determining indicators of skills to be improved. Furthermore, this will also have an impact on the success of their academic achievement in mathematics (Bara & Xhomara, 2020).

Meanwhile Suryanti and Supeni (2019) and Amin, et al. (2020), state that problem-based learning can improve students' soft skills, which include attitude, initiative, empathy and time management. Thus, it can be concluded that problem-based learning has the potential to improve students' problem-solving abilities. In addition, through the mathematical disposition indicators presented by Cooke (2015), it can also be concluded that problem-based learning has the potential to improve students' mathematical dispositions. According to Siagian et al. (2019), mathematics learning is an important matter to be considered in an effort to maximize students' mathematics learning achievement, so that mathematics teachers are expected to use the problem-based learning model by making qualified learning materials. Talking about qualified learning materials, of course, it will be related to various things that must be prepared by the teacher in delivering the material itself, both related to teaching materials, worksheets and learning aids that support the stages of this problem-based learning. The learning aids in mathematics are tools that can make it easier for students to follow the steps of the learning process in problem-based learning.

Problem-Based Learning assisted by tools such as computers, according to Mudrikah (2016), can be used effectively to stimulate reflective abstraction in students which in Action-Process-Object-Schema (APOS) theory is called as a method of constructing knowledge. The mathematics kit is also expected to function as a substitute for the role of computers that are capable of making abstract ideas and can be implemented or appear to be something concrete in mind, most do not even appear in the form of impressions (Arnon et al., 2013). Thus, the stages of problem-based learning with the help of mathematics kits are expected to condition the occurrence of reflective abstraction with regard to mental actions, mental processes, mental objects and schemes in students.

2. METHODS

This study involved 124 students of class eleven from two private high schools, one of which is a private school managed by an Islamic boarding school. From the two schools, 2 classes were each selected to be given problem-based learning assisted by a simple mathematics kit as an experimental class and problem-based learning without the help of a mathematics kit as the control class. All classes are given a prior mathematical ability (PMA) test to classify their students into high, medium and low ability categories.

In each school, the control group pretest-posttest experimental design was applied. The pretest and posts-test questions consist of essay questions about mathematical problem-solving ability of trigonometry and questionnaires about mathematical dispositions. The questionnaire instrument used to explore data about students' mathematical dispositions was an instrument whose validity had been tested consisting of 34 statement items. The 34 items contained statements about self-confidence; flexibility; persistence and persistence; interest, curiosity and inventiveness; monitor and reflection; application; and an appreciation of the role of mathematics.

3. FINDINGS AND DISCUSSION

Statistical results of Students' Mathematical Problem Solving (MPS) and students' Mathematical Disposition (MD) are on Table 1, Table 2, Table 3, and Table 4. The Tables show that learning factor tends to give higher MPS achievement and N-Gain than school category and PMA.

Table 1. PBL K Students' MPS Ability based on School Category and PMA

School Category	**PMA**	**Problem-Based Learning Assisted by Math Kits**					
		Pretest		**Posttest**		**Gain**	**N**
		r	**s**	**r**	**s**		
Non-Boarding School	High	21,33	2,75	53,67	2,87	0,65	6
	Medium	13,33	4,41	43,95	5,26	0,53	21
	Low	13,25	2,49	36,88	2,75	0,41	8
	Sub Total	14,69	4,84	44,00	6,85	0,52	35
Islamic Boarding School	High	4,20	3,11	57,20	6,34	0,79	5
	Medium	1,91	2,10	33,82	16,50	0,48	12
	Low	3,07	2,35	23,73	14,32	0,31	15
	Sub Total	2,78	2,45	33,09	18,33	0,45	32
Total	High	13,55	9,73	55,27	4,73	0,72	11
	Medium	8,94	6,55	40,61	11,08	0,57	33
	Low	6,61	5,49	28,30	13,86	0,34	23
	Total	9,00	7,12	38,79	0,31	0,51	67

Table 2. PBL Students' MPS Ability based on School Category and Prior Mathematical Ability

School Category	PMA	Problem-Based Learning					
		Pretest		Posttest		Gain	n
		r	s	r	s		
Non-Boarding School	High	5,40	2,52	47,00	9,04	0,64	5
	Medium	5,45	2,85	32,23	17,34	0,41	22
	Low	8,14	2,52	31,00	9,04	0,37	7
	Sub Total	6,00	2,86	34,15	13,89	0,44	34
Islamic Boarding School	High	3,75	2,12	42,25	16,26	0,57	4
	Medium	1,95	2,16	28,90	8,05	0,39	20
	Low	3,00	2,45	15,50	2,74	0,18	6
	Sub Total	2,40	2,19	28,00	10,73	0,37	30

Total	High	4,67	2,78	44,89	7,22	0,61	9
	Medium	3,79	2,93	30,64	12,49	0,40	42
	Low	5,77	3,68	23,85	9,51	0,28	13
	Total	4,31	3,13	31,27	12,79	0,41	64

Table 3. PBL K Students' MD based on School Category and Prior Mathematical Ability

School Category	PMA	Problem-Based Learning Assisted by Math Kits					
		Pretest		Posttest		Gain	n
		r	S	r	s		
Non-Boarding School	High	81,00	9,25	104,33	11,13	0,29	6
	Medium	81,38	6,69	101,33	10,30	0,25	21
	Low	82,00	8,77	99,75	10,63	0,23	8
	Sub Total	81,46	7,41	101,49	10,30	0,25	35
Islamic Boarding School	High	86,60	9,45	117,60	9,29	0,42	5
	Medium	83,67	11,05	110,08	7,61	0,34	12
	Low	85,47	10,96	107,93	6,61	0,29	15
	Sub Total	84,90	10,78	109,87	8,51	0,32	32
Total	High	83,55	10,42	110,36	12,46	0,35	11
	Medium	82,21	8,13	104,52	10,47	0,29	33
	Low	84,26	10,22	105,09	9,17	0,27	23
	Total	83,13	9,18	105,67	10,45	0,29	67

Table 4. PBL Students' MD based on School Category and Prior Mathematical Ability

School Category	PMA	Problem-Based Learning					
		Pretest		Posttest		Gain	n
		r	s	r	s		
Non-Boarding School	High	91,40	6,98	106,00	7,80	0,21	5
	Medium	91,91	12,56	104,73	9,94	0,17	22
	Low	92,43	7,91	101,14	10,31	0,12	7
	Sub Total	**91,94**	**11,65**	**104,18**	**10,15**	**0,17**	**34**

Islamic Boarding School	High	99,75	5,18	122,25	8,56	0,36	4
	Medium	92,55	10,71	103,40	13,07	0,15	20
	Low	96,17	18,71	106,33	10,69	0,13	6
	Sub Total	**94,23**	**12,06**	**106,50**	**12,20**	**0,18**	**30**
Total	High	93,22	10,42	108,78	12,46	0,22	9
	Medium	93,02	11,99	104,43	11,45	0,15	42
	Low	92,85	14,19	105,54	10,24	0,17	13
	Total	**93,02**	**11,81**	**105,27**	**11,13**	**0,17**	**64**

Learning factor has given higher MPS achievement and N-Gain than school category because of Non Boarding School (NBS) of Problem-Based Learning Assisted by Simple Mathematics Kits (PBL K) get almost similar N-Gain of MPS (posttest = 40.71 and N-Gain = 0.48) with Islamic Boarding School (IBS) of PBL K (posttest = 31.22 and N-Gain = 0.42) but get higher posttest score and N-Gain of MPS than NBS of Problem-Based Learning (PBL) (posttest = 30.87 and N-Gain = 0.39) and IBS of PBL (posttest = 24.77 and N-Gain = 0.32). According to the learning factor, the enhancement and the achievement of Students' MPS that acquire learning in PBL K tends to get higher than the students that acquire PBL.

Learning factor has given higher MD achievement and N-Gain than school category because of Non Boarding School (NBS) of Problem-Based Learning Assisted by Simple Mathematics Kits (PBL K) get almost similar N-Gain of MPS (posttest = 40.71 and N-Gain = 0.48) with Islamic Boarding School (IBS) of PBL K (posttest = 31.22 and N-Gain = 0.42) but get higher posttest score and N-Gain of MPS than NBS of Problem-Based Learning (PBL) (posttest = 30.87 and N-Gain = 0.39) and IBS of PBL (posttest = 24.77 and N-Gain = 0.32). According to the learning factor, the enhancement and the achievement of Students' MPS that acquire learning in PBL K tends to get higher than the students that acquire PBL.

Table 5. Resume of Two Ways Anova of MPS test and MD N-Gain with Learning and School Category factors

Source	**MPS Test N-Gain**			**MD test N-Gain**		
	F	P	H	F	P	H
Learning	5.75	0.018	Rejected	37.20	0.000	Rejected
School Category	0.82	0.368	Accepted	5.11	0.026	Rejected
Interaction	0.23	0.634	Accepted	1.92	0.168	Accepted

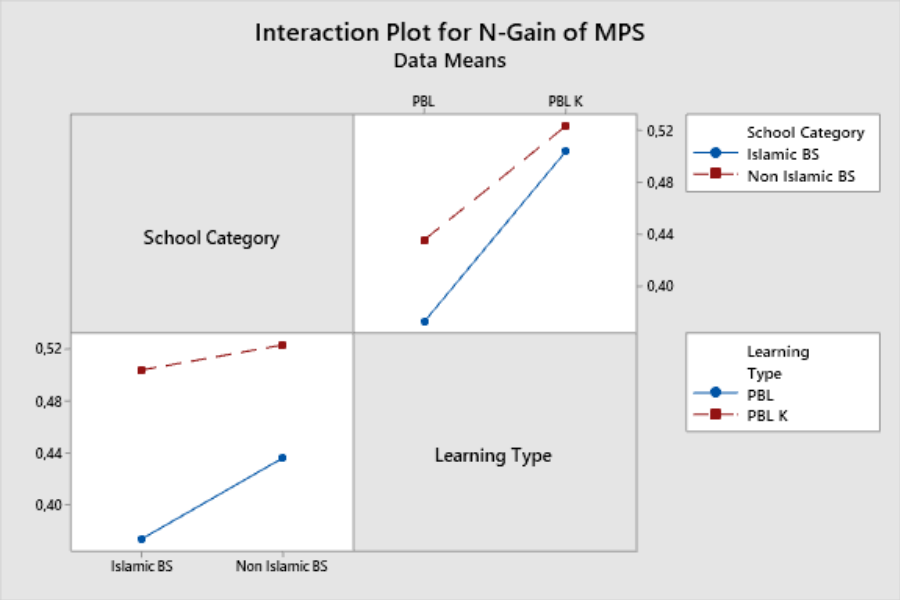

Figure 1. Interaction Plot of Learning and School Category (N-Gain Test of MPS)

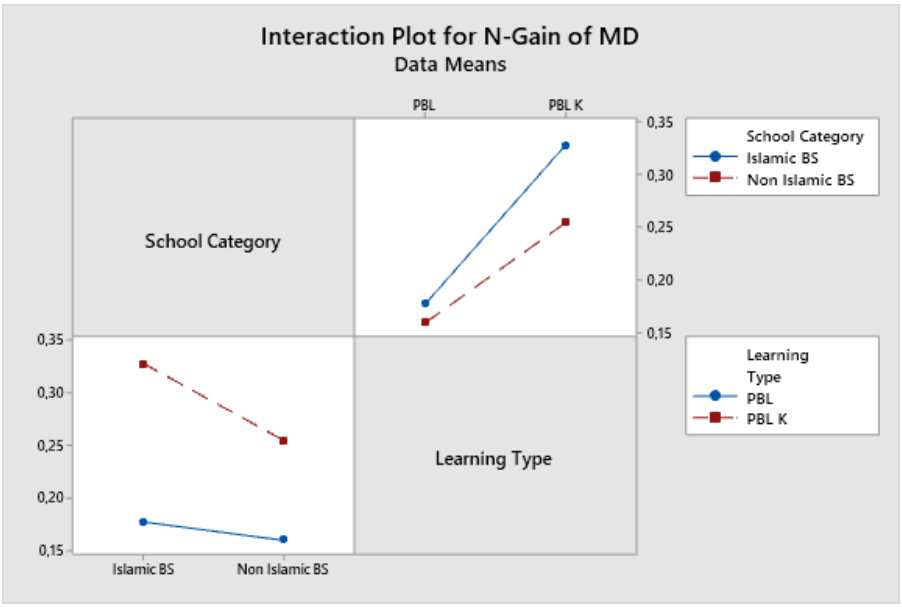

Figure 2. Interaction Plot of Learning and School Category (N-Gain Test of MD)

From Table 5, Figure 1 and Figure 2, we can conclude that there is no significant difference between MPS test N-Gain based on School Category and there is no interaction between School Category and learning type of MPS test N-Gain. We also can conclude that MPS test N-Gain are significantly different based on learning type; MD N-Gain are significantly different based on school category; and there is an interaction between school category and learning type of MD N-Gain.

Table 6. Resume of t-test or Mann Whitney test of Mathematical Problem Solving (MPS) N-Gain and Mathematical Disposition (MD) N-Gain based on Learning and School Category Factors

Comparison	MPS Test N-Gain			MD Test N-Gain		
	t/W	P	H	t/W	P	H
PBL K and PBL	4934.50	0,007	Rejected	4984,50	0,010	Rejected
NBS and IBS	4972,50	0,054	Accepted	4165,50	0,074	Accepted

From table 6 above, it can be concluded that the MPS Test N-Gain and MD Test N-Gain for learning PBL K and PBL are significantly different. Likewise, the MPS Test N-Gain and MD Test N-Gain for Non-Boarding Schools and Islamic Boarding Schools are significantly different.

Table 7. Resume of t-test or Mann Whitney test of MPS N-Gain and MD N-Gain between two Learning types on Students form non-boarding school and Students form Islamic Boarding School

School Category	N-Gain	Comparison	t	W	P	H_0
NBS	MPS Test	PBL-K & PBL	-	1359,00	0,109	Accepted
	MD Test	PBL-K & PBL	4,00	-	0,000	Rejected
IBS	MPS Test	PBL-K & PBL	-	1076.00	0.342	Accepted
	MD Test	PBL-K & PBL	0.49	-	0.623	Accepted

From Table 7, it can be concluded that the MD Test at the Non-Boarding School and the Islamic Boarding School between students who received PBLK and students who received PBL was significantly different. Meanwhile, the MPS Test in the two types of schools between students who received PBLK and students who received PBL did not significantly different.

Table 8. Mann-Whitney test or t-test of MPS N-Gain and MD N-Gain between School Categories on PBL K and PBL

Learning	Comparison of School Category	N-Gain	t	W	P	H_0
PBL K	NBS and IBS	MPS Test	-	1243.50	0.506	Accepted
	NBS and IBS	MD Test	-3.08	-	0.003	Rejected
PBL	NBS and IBS	MPS Test	1,39	-	0.169	Accepted
	NBS and IBS	MD Test	-5.48	-	0,000	Rejected

From the data in Table 8, it can be concluded that the MD Test of students who received PBL K between Non-Boarding School and Islamic Boarding School students is significantly different. Meanwhile, for the MPS Test, students who received PBLK and students who received PBL did not significantly differ.

Table 9. Two Way ANOVA of MPS N-Gain and MD N-Gain With learning Factor and PMA Factor

Source	MPS Test N-Gain			MD Test N-Gain		
	F	P	Ho	F	P	Ho
Learning Type	5.38	0.022	Rejected	24.64	0.000	Rejected
PMA	14.44	0.000	Rejected	2.81	0.064	Accepted
Interaction	0.59	0.554	Accepted	0.28	0.758	Accepted

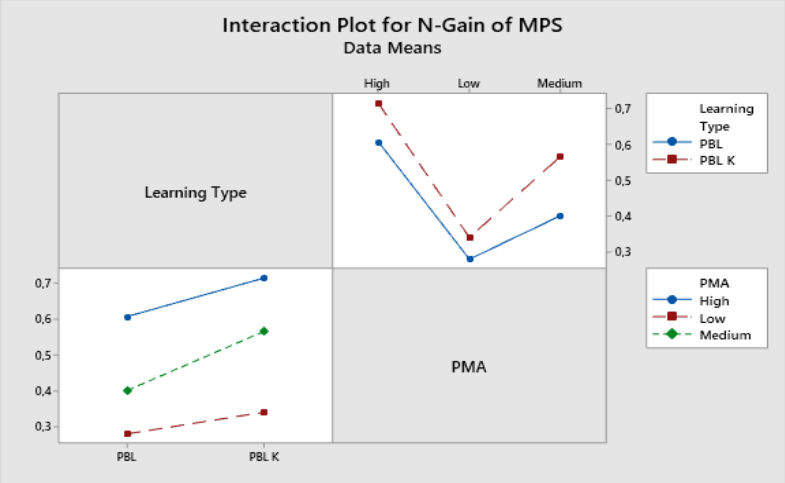

Figure 3. Interaction Plot of Learning and PMA (N-Gain Test of MPS)

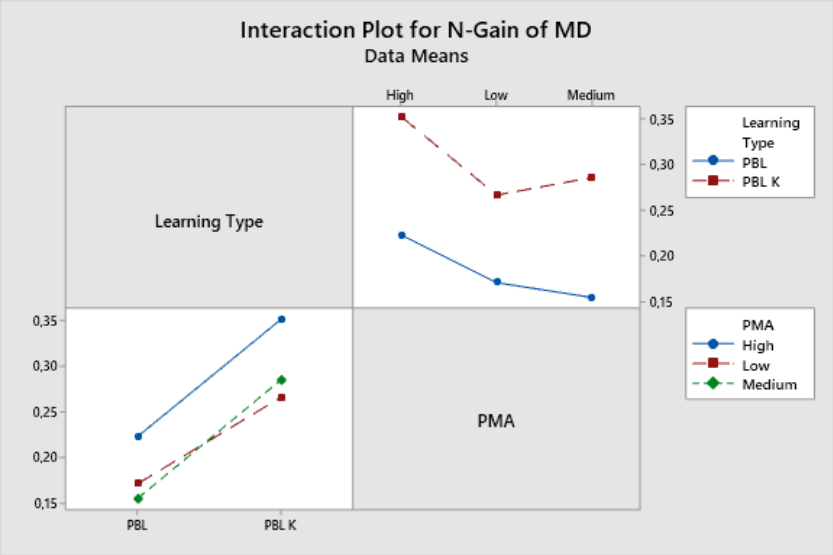

Figure 4. Interaction Plot of Learning and PMA (N-Gain Test of MD)

Table 10. Mann-Whitney test or t-test of MPS N-Gain and MD N-Gain between PMA Categories from Two Learning Types

Learning Type	N-Gain	PMA Comparison	T	W	P	H_0
Problem-Based Learning Assisted by Simple Mathematics Kit	MPS Test	High and Medium	-	392.50	0.000	Rejected
		High and Low	-	310.00	0.000	Rejected
		Medium and Low	-	1152.00	0,000	Rejected
	MD Test	High and Medium	1.29	-	0.229	Accepted
		High and Low	-	351.00	0.219	Accepted
		Medium and Low	-	1156.00	0.000	Rejected
Problem-Based Learning	MPS Test	High and Medium	0.93	-	0,375	Accepted
		High and Low	-	160.50	0,005	Rejected
		Medium and Low	-	1154.00	0.469	Accepted

		High and Medium	-1.55	-	0.146	Accepted
	MD Test	High and Low	-2.23	-	0.039	Rejected
		Medium and Low	-1.15	-	0.261	Accepted

From the statistical calculation, it can be said that the data described, the mathematical problem-solving ability and mathematical dispositions of students who used problem-based learning assisted by simple mathematics kit was better than students who only received problem-based learning. These findings informed the effectiveness of PBLK compared to PBL. PBL, as many researchers believed, is very applicable in teaching mathematics (Holmes & Hwang, 2016; Kurniawan et al., 2021). Another calculation also reported that students from Islamic boarding schools show better problem-solving ability when studying mathematics with problem-based learning assisted by simple math kits. This finding supports a statement from Albalaw (2017) and Astuti et al. (2019) that teaching media is helpful for increasing students' mathematical ability. Moreover, students from Islamic boarding private school gain better problem-solving ability than students from non-boarding private school, especially students who have high and medium prior mathematical abilities.

4. CONCLUSION

The findings of this study were that the participants still had difficulty solving the problem given by using the sine and cosine rules. Although many of them obtain an appropriate mental structure at the level of action and process, they still did not have the appropriate mental structures at the level of objects and schemas in APOS theory analysis. Even there are still many students who have not been able to reach the level of action at all. Nevertheless, it appears that Problem-Based Learning assisted by mathematics kits along with student activity sheets were able to build mental structures at action and process levels. While at the object and schema level, students still need to improve their understanding of other trigonometric materials such as trigonometric functions of an acute angle and of any angle, right triangle trigonometry, addition formulas and trigonometric identities. This is undeniable because the students' understanding of the sine and cosine rules concept cannot stand alone but tend to depend on their understanding of other trigonometric materials. To overcome this problem, the teacher should first believe in the students' prior mathematical abilities before implementing their learning approach. Related to the use of APOS theory analysis as a psychological analysis in revealing the ability to understand students' mathematical concepts, it seems that the teachers must have the ability to do so.

The difficulty of participants in solving the trigonometric problems given to them arises because they have not been able to reach the level of objects and schemas in APOS theory. This clearly requires serious attention from teachers who teach mathematics. The teacher must pay more attention to the level of student achievement while studying mathematics. The learning process must also be able to measure the level of student achievement. Thus, the right instruments are needed in an effort to measure the level of achievement that can be conducted by future researchers.

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