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Improving Students' Mathematical Problem-Solving Ability through the Application of Problem-Based Learning by Using Geometer's Sketchpad

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This research purposed to describe the mathematical problem-solving ability of students who applied problem-based learning by using Geometer's Sketchpad program. This was then compared against that of students who applied problem-based learning without using Geometer's Sketchpad program and that of students who applied conventional learning. The results were analysed based on pre-existing ability in mathematics (superior, inferior). This study included quantitative descriptive research with quasi experimental approach. The results of the research showed a significant difference in mathematical problem-solving ability of students who applied problem-based learning by using Geometer's Sketchpad (PBLu), students who applied problem-based learning without using Geometer's Sketchpad (PBLw), and students who applied conventional-based learning (CBL). The results also showed that improvement of mathematical problem-solving skills of both superior and inferior PBLu students is better than CBL students; the improvement of mathematical problem-solving ability of both superior and inferior PBLw students is not better than CBL students; and the improvement of mathematical problem-solving ability of superior PBLu students is better than PBLw students.

Key words: *Mathematics, Problem Solving, Learning, Geometer*

Introduction

Mathematics is one of the school subjects that is taught at all levels of education, ranging from elementary school, junior high school, and senior high school. According to a reference (Kementerian et al., 2013) in the 2013 curriculum content standard, the purposes of teaching mathematics in schools are to:

- Train ways of thinking and reasoning in drawing conclusions, for example through investigation, exploration, experimentation, showing similarities, differences, consistencies and inconsistencies.
- Develop creative activities that involve imagination, intuition, and discovery by developing different thoughts, original, curiosity, prediction-making, and experimentation.
- Develop problem-solving skills.
- Develop the ability to convey information or communicate ideas through, among others, oral talks, graphics, maps, diagrams, and explaining ideas

Likewise, the National Council of Teachers of Mathematics, (2000) stipulates that there are five process skills, which are included in the process standards, that students need to possess through learning mathematics, namely: "(1) problem solving; (2) reasoning and proof; (3) communication; (4) connection; and (5) representation". Based on several opinions, it appears that problem solving ability is an important aspect of mathematics learning. This ability is part of high-level mathematical thinking that must be developed in the process of learning mathematics. In addition, learning mathematics not only trains high-level thinking skills, but has several other objectives, as revealed by (Suryadi and Herman), which states that there are various abilities that can be developed through mathematics, and these abilities fall into three categories that are necessary for children: abilities that may be used to continue education at a higher level, abilities used in everyday life and in the community, and abilities that support work-related needs.

The importance of mathematical problem solving is emphasised in the National Council of Teachers of Mathematics, (2000) which states that problem solving is an integral part of mathematics learning, so it cannot be separated from mathematics learning. These opinions support the idea that mathematical problem-solving abilities are very important. Therefore, a person's ability to solve mathematical problems needs to be continuously trained so that they are able to solve the various problems they face.

Geometry is a mathematical subject that requires high-level mathematical abilities to understand. According to NCTM (Siregar, 2009), the abilities that students must possess to study geometry are: 1) the ability to analyse the characteristics and properties of geometric shapes in two or three dimensions and construct mathematical arguments about geometric relationships; 2) the ability to determine the position of a point, illustrate its spatial relationships by using coordinate geometry, and link it to other systems; 3) the ability to apply transformations and use symmetry to analyse mathematical situations; and 4) the ability to use visualization, spatial reasoning, and geometric models to solve problems. By mastering these abilities, it is expected that students' mastery of geometry material will improve.

In learning geometry, it should also be noted that the role of teaching aids is closely related to abstract geometrical objects. When Van Hiele's theory emerged, the type of mathematics employed by teaching aids was still limited to concrete objects; however, with the development of technology, a new type of prop, known virtual props, has been developed. This tool has the characteristics of semi-concrete objects and can be manipulated directly by students in activity-based learning. For example, Geometer's Sketchpad (GSP) is a dynamic mathematical software that studies geometry, algebra, calculus, and so on. There are several considerations regarding the use of GSP in geometry learning in junior high school students. According to Hoehn (Lam, 2007) "students who are taught geometry with GSP can prove the theorems that exist in geometry". Furthermore (De Villiers, 1998) said, "With GSP students are able to transform images dynamically, students are able to examine a series of similar cases and direct them to generalise to the properties of triangles, rectangles, circles, and other geometric configurations." Students who use GSP have the opportunity to see different forms of geometrical concepts.

Other necessary efforts in improving students’ problem-solving skills include the choosing of a relevant learning model or strategy. One of these involves applying problem-based learning, which is a learning process that teaches students to recognise problems, formulate problems, find solutions, test temporary answers by conducting an investigation (finding facts through sensing), and eventually, draw and present conclusions verbally and in writing. This is in accordance with the opinion of reference (Stepein, 2000), which states that problem-based learning is a learning model that directs students to solve mathematical problems through the stages of the scientific method. This is so that students can learn knowledge related to a problem and develop the skills necessary to solve it. In addition to choosing relevant learning models, the teacher must also be able to apply technological developments in the learning process more meaningfully. The workload of a teacher becomes lighter by them enlisting the help of the Geometer's Sketchpad program, meaning that during the process of material abstraction, students are better able to understand the material delivered. A review of the material above encouraged the conducting of this research, which focused on the application of a problem-based learning model assisted by the Geometer's Sketchpad program to improve the mathematical problem-solving skills of seventh-grade junior high school students and analysis of these skills in terms of the students' former mathematical abilities.

Experimental Method

Based on the research objectives, this research uses a quasi-experimental method with a control group design that was not equivalent (the non-equivalent control group design). This design is used because the institution where the research was carried out objected to the random grouping of students, so the researcher accepted the state of the subject as rudimentary. The population in this research was VII grade students of a public junior high school, 10 Tasikmalaya City, West Java in 2016. The sample in this research was taken using a purposive sampling technique. The research sample was taken from three classes of all VII grade students in the public junior high school, 10 Tasikmalaya City. Two of these classes were used as experimental classes and the remaining one was used as a control class. The sampled classes were Class VII G, which was used as the first experimental class for problem-based learning using the GSP program (PBLu); Class VII I, which was used as the experimental class for problem-based learning without using the GSP program (PBLw); and the Class VII H, which was used as the control class for conventional-based learning (CBL). Based on the assumption that every student in any school has different early abilities (superior and inferior), researchers used a controlled variable in the form of differences in students' former mathematical abilities.

The test instruments used, which were in the form of questions to measure students' mathematical problem-solving abilities, were adapted from Schoen and Oehmke and comprised the following indicators: 1) solving problems that arise in mathematics or in other contexts involving mathematics; 2) applying and adapting various approaches and strategies to solve problems; 3) building new mathematical knowledge through problem solving; 4) applying and adjusting various approaches and strategies to solve problems; 5) solving problems that arise in mathematics or in other contexts involving mathematics; and 6) monitoring and reflecting on mathematical problem solving processes. The form of test questions on students' mathematical problem-solving skills in the form of descriptions consists of 6 items. To be more focused, students' were directed and trained to work on mathematical problem-solving questions by using problem solving steps according to Polya (Suherman et al., 2001), which consists of "1) understanding the problem 2) completion planning (plan a solution) 3) calculate (carrying out the plan) 4) check the results (looking back)".

To determine whether or not there were differences in each group and whether or not there is an interaction between the independent variable/controlled variable on the dependent variable, in accordance with the stated hypothesis, researchers used a two-way ANOVA test, followed by a pair test (post-hoc), namely the Scheffe Test

Result and Discussion

This research purposed to describe and compare the improvement in mathematical problem-solving abilities between students who applied problem-based learning using GSP (PBLu), those who applied problem-based learning without using GSP (PBLw), and those who applied conventional based learning (CBL). Besides that, this research also analysed the interaction between groups of learning based on initial ability in mathematics (KAM). The results of students' mathematical problem-solving ability, both pre-test and post-test scores, can be seen below. The increase in students' mathematical problem-solving abilities is shown by the n-gain score. A general description of the quality of students' mathematical problem-solving abilities based on each student's Early Mathematical Ability (EMA) factors are presented in Table 2.

Table 1: Students' Mathematical Problem-Solving Ability Based on Student Groups

Early Mathematical Ability	Treatment Methods	Average Problem-Solving Ability		
		Pre-test	Post-test	N-gain
Superior	PBLu (14)	10,00	65,50	0,62
	PBLw(13)	6,77	48,77	0,45
	CBL (15)	5,87	45,53	0,42
Inferior	PBLu (23)	4,83	34,91	0,32
	PBLw (27)	5,30	30,07	0,25
	CBL (24)	4,25	28,25	0,26
Total	PBLu (37)	6,78	46,49	0,43
	PBLw (40)	5,78	36,15	0,32
	CBL (39)	4,87	34,90	0,32

In Table 1, it can be seen that, in each early ability group, the average n-gain in mathematical problem-solving abilities of students who applied problem-based learning with GSP is higher than that of both students who applied problem-based learning without GSP assistance and students who applied conventional learning. The highest average gain in mathematical problem-solving ability was obtained by students in the superior group, and the lowest average gain in mathematical problem-solving ability was obtained by students in the inferior group. This illustrates that the superior group is more able to absorb learning outcomes and can therefore obtain higher gain results than the inferior group; however, in order for this trend to be accepted, it is necessary to conduct further testing with inferential statistical tests, described below.

- Comparison of Increased Mathematical Problem-Solving Ability Based on Learning Classes

The improvement in mathematical problem-solving abilities of PBLu, PBLw and CBL students is described and analysed by calculating the gain in each of the three classes through the normalised gain formula. The results showed that the average improvement in mathematical problem-solving abilities of PBLu class students was 0.43; the average improvement for PBLw classes and CBL classes was 0.32. It appears that for PBLu, PBLw, and CBL classes, the average increase in mathematical problem-solving skills was in the medium criteria.

In addition, to figure out the existence or absence of mean differences between the three groups, an ANOVA test was performed, and the results showed that there were differences between the mathematical problem-solving skills of PBLu, PBLw, and CBL students. Based on the results of the Scheffe test, it can be concluded that the improvement in mathematical problem-solving ability of PBLu students is significantly different from that of PBLw and CBL students, and the improvement in mathematical problem-solving ability of PBLw students is not significantly different from that of CBL students.

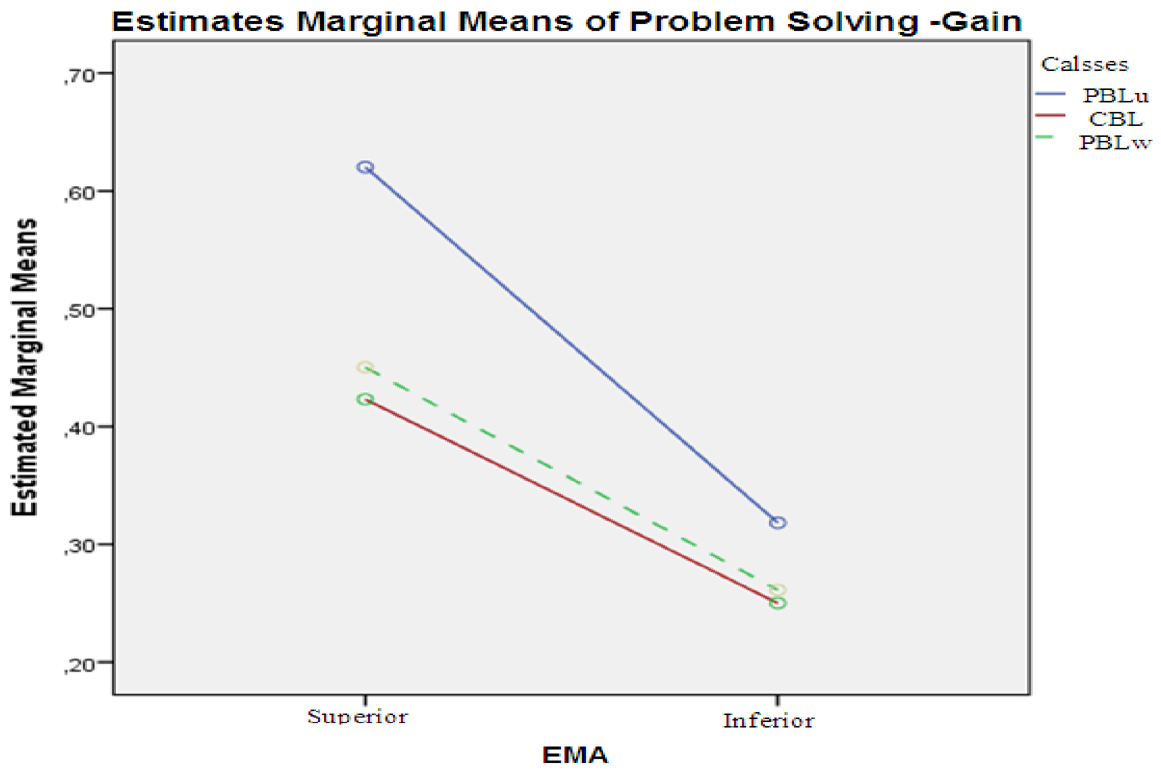
- Interaction between Learning Classes and Early Mathematical Ability (EMA) in Mathematical Problem-Solving Ability

In addition to looking at differences in the improvement of problem solving abilities based on class (giving treatment), the research also investigated the presence or absence of interaction between learning and the early ability of mathematics in improving mathematical problem-solving abilities. A two-way ANOVA test was used to analyse this. The results of the analysis indicate that the learning class and the early mathematical abilities of students significantly influence the improvement of students' mathematical problem-solving abilities. This shows that the interaction between learning classes and KAM has a significant influence on improving students' mathematical problem-solving ability. This means that there are at least two learning classes that interact with students' early mathematical abilities to improve students' mathematical problem-solving abilities. The Scheffe test was used to analyse which learning interacts with early mathematical abilities.

The results of the analysis showed: 1) the improvement in the mathematical problem-solving abilities of students who applied problem-based learning assisted by the GSP program was better than that of students who applied problem-based learning without the help of the GSP program, as seen from early mathematical abilities (superior and pure); 2) the improvement in the mathematical problem-solving abilities of students who applied problem-based learning assisted by the GSP program was better than that of students who applied conventional learning, as seen from the early mathematical abilities (superior and pure); and 3) the improvement in the mathematical problem-solving abilities of students who applied problem-based learning without the help of the GSP program was no better than that of students who applied conventional learning, as seen from early mathematical abilities (superior and pure), or the improvement in the mathematical problem-solving abilities of students who applied conventional learning was better than students who applied problem-based learning without the help of the GSP program, as seen from the early mathematical abilities (superior and inferior).

Graphically, the interaction between learning classes with early mathematical abilities and the improvement in mathematical problem-solving skills is shown in Figure 1

Figure 1. Interaction between Learning with Early Mathematical Ability (EMA) in Mathematical Problem-Solving Ability



In Figure 1, it appears that there is an interaction between learning (PBLu and CBL, PBLu and PBLW) with early mathematical abilities (superior and inferior) and the improvement of mathematical problem-solving abilities. It turned out that the application of PBLu learning tended to significantly improve mathematical problem-solving abilities in both the superior group and the inferior group; however, there is no interaction between learning (CBL and PBLw) with the early ability of mathematics (superior and inferior). This is because the difference in mean increase between CBL learning and PBLw learning in the superior group of students is not significantly different from the increase in the inferior group students. Thus, although PBLw learning has not played an optimal role when compared to CBL learning, this study shows that problem-based learning (PBLw) with the help of GSP can improve students' mathematical problem-solving skills, both in the superior group and in the inferior group.

The results of this study generally show that the improvement of mathematical problem-solving skills in students who use PBLu is better when compared to PBLw and CBL classes. This shows that the use of the GSP program as a learning medium can help and facilitate students in understanding geometrical material. Another effect of computer-assisted learning is that students become interested in learning mathematics. Students can also prove and repeat the material they have learned. This is in accordance with the opinion of Heinich (Kariadinata, 2000), who states that the advantages of computers as learning media include: 1) students can learn according to their ability and speed in understanding the knowledge and information displayed; 2) student learning activities can be controlled; 3) students have the facilities to repeat if needed; 4) students are assisted by getting feedback; 5) learning media creates an effective learning climate for students who are slow, but can also spur the effectiveness of learning for students who are faster; 6) provision of feedback and confirmation of learning outcomes can be programmed. This opinion is supported by Nuryadin (Amalia, 2004), who states that the benefits that can be obtained by students from the use of computer media in learning activities include: attracting interest or attention, encouraging students to learn, concretising phenomena that occur, and giving direct experience that helps facilitate students' cognitive understanding.

These results made the researchers more interested. To further investigate this field, the researchers conducted interviews on the use of GSP in mathematics learning. One of the questions was whether you (the student) are helped working on mathematics with the GSP program? Students' answers mostly stated that the GSP program helped them to understand mathematical concepts. It can therefore be inferred that students' who learn with GSP have a deeper and better understanding than students who learn without GSP. Based on the results of the interviews, the researcher can surmise that for the students who carried out their learning with the help of the GSP program, the assimilation of mathematical concepts was better because the concept was visualized in the GSP program. These students' retention was better, so when working on test questions involving mathematical problem-solving skills, these students found it easier to understand the problem and solve it. These results illustrate to us that students who use the GSP program to help them understand mathematical concepts will improve their mathematical problem-solving skills more effectively than students who carry out learning without using the GSP program

Conclusion

Based on the results of the analysis, findings, and discussion on improving the problem solving abilities of students who applied problem-based learning with the use of GSP (PBLu), students who applied problem-based learning without the use of GSP (PBLw), and students who applied conventional learning (CBL), several conclusions can be drawn. These conclusions are as follows: 1) There is a significant difference in the improvement of mathematical problem solving ability of PBLu students, PBLw students, and CBL students. 2) The improvement of mathematical problem solving skills of superior students and PBLu students is better than CBL students. 3) The improvement of mathematical problem solving ability of superior and inferior PBLw students is not better than that of CBL students. 4) The improvement of mathematical problem solving ability of superior and inferior PBLu students is better than PBLw students.

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