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An Effort to Improve Mathematical Problem Solving Ability of Middle Secondary School Students through Autograph-Assisted Mathematics Realistic Education Approach

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Abstract This study aims to investigate (1) the improvement of students' mathematical problem solving ability (MPSA) through Autograph-assisted realistic mathematics education approach (ARME), (2) The existence of the interaction between the learning approach and the initial mathematical ability (IMA) of the improvement of students MPSA, (3) the process of solving mathematical problems. The instrument used consisted of the MPSA test. Data were analyzed through two-way ANOVA. Before using ANOVA, homogeneity and normality are first tested. Based on the results of the analysis, the findings of the study are: (1) the improvement in MPSA of students in ARME class is higher than the improvement in MPSA of students in conventional class, (2) there is no interaction between learning approach with IMA in improving MPSA, (3) The process of solving mathematical problems that made by the students in ARME class is better than students in conventional class, that means students in the ARME class show more systematic and directed problem solving steps. Research findings recommend that the ARME approach be one of the learning approaches used in schools, especially to improve MPSA.

Keywords: *mathematical problem solving ability, realistic mathematics education approach, autograph software*

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1. Background

Education is a place where humans are fostered, grown, and developed their potentials. The virtue in education is the learning process. According to Nesusin, et.al.: "The learning process must provide several benefits for students so that they can develop their abilities fully" [1]. The more potential a person is developed, the more able he is to face changes in the conditions in life that are always developing in the present and in the future that occur globally. Learning that can benefit a lot is learning mathematics. According to Freudenthal, "learning mathematics is doing mathematics by solving mathematical problems as dynamic and interactive activities such as finding, exploring, looking for relationships and proving it" [2]. Shimizu (in Isoda, 2010) explains that the teaching approach which includes innovative learning is teaching mathematics which starts from the problems of children in the real world [3].

In building their knowledge, students must be directly involved in concrete experiences before learning abstract mathematical concepts, then invited to focus on finding mathematical concepts and connect them to existing knowledge so that students will feel involved in the discovery of mathematical concepts. In line with this statement, teaching mathematics should give high-level thinking skills (high order thinking skills, abbreviated HOTS) which includes the ability of understanding, reasoning, connection and representation, and problem solving abilities [4]. In fact, in evaluation report by TIMSS (Trend in International Mathematics and Science Studies) year 2003, 2007, and 2012 [5], show that mathematical problem solving skills of Indonesian students is low [6]. Some other research results show the weaknesses of students MPSA [7,8,9].

Educational experts suspect that MPSA students are in the low category due to learning factors that have been run in conventional schools [10,11,12,13], even though the MPSA can be developed in schools; one way to develop it is through Realistic Mathematic Education (RME). Gravemeijer stated that RME is a learning approach that starts every beginning of learning by proposing real-life problems (called problem scenarios) to students in small groups (collaborative) [14]. Experts believe that RME can improve mathematical problem solving abilities [15,16,17].

During the process of RME approach, students will be more easily involved in mathematical problem solving if learning is combined with the use of computer and communication technology (ICT). The use of ICT is one of the six principles of learning mathematics; technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and improves students' learning"; or application in class, the use of ICT can be integrated to several learning approach [18]. Karnasih states that there are four different approaches that can be implemented in integrating ICT to teaching and learning mathematics: 1) Expository learning; 2) Inquiry based learning; 3) Cooperative learning; and 4) Individual learning [19].

The above statement from Karnasih shows that the use of ICT is suitable if integrated in learning to improve mathematical problem solving skills. One software that can help teaching mathematics is autograph. Autograph itself was recommended by Curriculum and Evaluation Standards for School Mathematics [20]. By using autograph, students can explore, investigate and search. By using autograph, students get an aid to solving mathematical problems. Students can retry solving the problem in a short period of time than just using hands, so that from the experiment students can find, construct and deduce mathematical principles, and finally understand mathematical concepts.

Based on the literature study, it can be said that autograph-assisted realistic mathematics education approach (ARME) can be expected to improve students' mathematical problem solving skills.

2. Theoretical Framework

Realistic Mathematics Education (RME) is a teaching and learning theory in mathematics education that was first introduced and developed by the Freudenthal Institute in the Netherlands. This theory has been adopted by a large number of countries all over the world such as England, Germany, Denmark, Spain, Portugal, South Africa, Brazil, USA, Japan, and Malaysia. [21]. The present form of RME is mostly determined by Freudenthal's view on mathematics [22].

Freudenthal has two important points of views, that is, mathematics must be connected to reality and mathematics is as human activity. First, mathematics must be close to children and be relevant to everyday life situations. However, the word 'realistic', refers not just to the connection with the real-world, but also refers to problem situations which real in students' mind. For the problems to be presented to the students this means that the context can be a real-world but this is not always necessary. De Lange stated that problem situations can also be seen as applications or modeling. Second, the idea of mathematics as a human activity is stressed. Mathematics education organized as a process of *guided reinvention*, where students can experience a similar process compared to the process by which mathematics was invented. The meaning of invention is steps in learning processes while the meaning of guided is the instructional environment of the learning process. For example, the history of mathematics can be used as a source of inspiration for course design. Moreover, the reinvention principle can also be inspired by informal solution procedures. Informal strategies from the students can often be interpreted as anticipating more formal procedures. In this case, the reinvention process uses concepts of mathematization as a guide.

Two types of mathematization which were formulated explicitly in an educational context by Treffers are horizontal and vertical mathematization. [23]. In horizontal mathematization, the students come up with mathematical tools which can help to organize and solve a problem located in a real-life situation. The following activities are examples of horizontal mathematization: identifying or describing the specific mathematics in a general context, schematizing, formulating and visualizing a problem in different ways, discovering relations, discovering regularities, recognizing isomorphic aspect in different problems, transferring a real world problem to a mathematical problem, and transferring a real world problem to a known mathematical problem. On the other hand, vertical mathematization is the process of reorganization within the mathematical system itself. The following activities are example of vertical mathematization: representing a relation in a formula, proving regularities, refining and adjusting models, using different models, combining and integrating models, formulating a mathematical model, and generalizing.

Freudenthal stated that "horizontal mathematization involves going from the world of life into the world of symbols, while vertical mathematization means moving within the world of symbols."[24]. But he adds that the difference between these two types is not always clear cut. Related to the ability of solving problem, in the 2013 Indonesian Curriculum, it is stated that one of the abilities expected to be grasp by the students in learning mathematics is the ability to solve problems or often called problem solving [25]. According to Lester the problem is "a situation in which an individual is called to perform a task for which there is no ready algorithm which determines completely the methods of solution." [26]. Problem is a situation where an individual or group is open to solve it but there is no algorithm that can be used to achieve the resolution of the problem. If the answer to a problem has been obtained then it is no longer called a problem.

According to NCTM problem solving is central to the investigation and application of knowledge and should be included in the school curriculum to provide a context for learning and applying mathematical ideas. [27]. Problem solving has the meaning of being involved in a task whose solution is not known beforehand. In order to find solutions, students must gather various information and through this process, they develop new understanding in mathematics.

Furthermore, mathematical problem solving ability (MPSA) is the ability to formulate, propose and investigate problems, the ability to collect, organize, and analyze problems from a mathematical point of view, the ability to determine suitable strategies, the ability to apply the knowledge and skills possessed, and the ability to reflect and monitor the mathematical thinking process.

According to Polya, when someone solves a problem, he will go through a series of the following steps: (1) understanding the problem, (2) arraning the problem solving planning, (3) applying problem solving planning, and (4) rechecking, with the reason the strategy is used to use. [28].

Figure 1. Polya's Problem Solving Cycle

Related to autograph software, this kind of software is very useful in teaching learning mathematics. Through the autograph software, students can compare the work to solve mathematical problems manually with those generated by the autograph software. Therefore, this software can be combined with the RME approach for the purpose of improving mathematical problem solving abilities (MPSA) of middle secondary school students.

3. Research Questions

The research try to improve mathematical problem solving ability of the middle secondary school students through autograph-assisted realistic mathematics education approach (ARME). Research questions are:

1. Is the improvement in MPSA of students in the ARME class higher than the improvement in MPSA students in conventional classes?
2. Is there an interaction between learning approach and IMA on improving MPSA?
3. Is the process of solving mathematical problems made by students in the ARME class better than students in conventional class?

4. Research Methods

In this study, the Autograph-assisted RME approach (ARME) was applied in the experimental class and the conventional approach was used in the control class to convey mathematics material related to statistical problems. The research design used was pretest-posttest control group design. In this design, there are two groups of students where each group is given a pretest to determine the initial mathematical ability (IMA), then posttest to see the final state of mathematical problem solving abilities after being treated.

This research is quasi-experimental because the class used has been formed before. Subject of the study is 36 students of VII SMPN 2 Beringin Deli Serdang. The object of the research was the students' mathematical problem solving abilities (MPSA) and student activities in the classroom. The instrument used consisted of the MPSA test, observation sheet for student activities, and interview guidelines. After finishing MPSA test, the activity continued to interview stage. Subjects to be interviewed consisted of students with high, medium and low MPSA categories. The interview with the subject was done based on the answer errors written by the students on the MPSA test answer sheet. Interviews are open standards that give students the freedom to develop opinions. Interviews are conducted more in depth depending on the situation and condition of the respondent. Teaching learning activity conducted by the teacher in the experimental class consists of grouping students into small groups consisting of 4 to 5 students. Each group is given a set of student activity sheet (SAS) consisting of mathematical problems to enable students to achieve mathematical problem solving abilities. The teacher directs students to start working on problems in SAS from number 1 to problem number 3. At the end of the meeting, the teacher guides students to share the results of solving problems, discussing, and arguing with friends from other groups. In this case, the teacher acts as a moderator and directs students to make conclusions on what he learned from today's classroom activities. This kind of activity repeated at each meeting until the time for the posttest arrives. In conventional classrooms, teachers convey mathematics topics through expository methods. Through expository method, the teacher describes the topic of mathematics as completely as possible, then, provides examples of problem solving. Finally, the teacher asks students to solve similar problems.

5. Result and Discussion

The study of students' mathematical problem solving abilities (MPSA) presented here includes the description, summary of the results of hypothesis testing and analysis of data based on learning, as well as an analysis of the combined effect (interaction) between learning approach and IMA factors (high, medium and low). The learning factors used are Autograph-assisted realistic mathematics education approach (ARME) and conventional approach. At ARME class, the students are learning in small group to solving mathematical problems presented in students activity sheet (SAS). While, in control class (conventional class) the students are not grouped, the teacher explained math topic to all students at the classroom.

5.1. The Difference of Mathematical Problem Solving of The Students

Overall, the data has been tested for normality and homogeneity for both the two-way ANOVA test and the interaction test. The results are significant. Test of average difference in mathematical problem solving ability (MPSA) was carried out through two-way ANOVA, the results are shown in Table 1.

Based on the test results in Table 1, it can be concluded that the effect of ARME on students' mathematical problem solving abilities is better than the influence of conventional learning.

Table 1. ANOVA Result For MPSA Data

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	175.947[a]	5	35.189	3.260	.012
Intercept	12886.613	1	12886.613	1193.985	.000
Learning approach	59.511	1	59.511	5.514	.022
IMA	98.503	2	49.251	4.563	.014
Learning approach*IMA	2.226	2	1.113	.103	.902
Error	625.990	58	10.793		
Total	18292.000	64			
Corrected Total	801.938	63			

a. R squared = .219 (Adjusted R Squared = .152).

MPSA in the ARME class is better than MPSS in conventional class because in the class that implements the ARME approach students solved mathematical problem solving regularly and systematically It means, math problems have designed with the objective to improve students MPSA. The mathematical problems that students solve in this class are documented in the Student Activity Sheet (SAS). Problems in SAS are designed based aspects, which are understanding problems, planning strategies, implementing strategies, and reflection. In this study, reflection is the activity to interpreted as making a conclusion based on the solution obtained.

In conventional class, students accept math topics that are explained by the teacher, get ways to solve mathematical problems from the teacher's explanation, and practice solving problems according to what the teacher teaches. The mathematical problems that are resolved are still routine problems that do not require problem solving steps. The following is the research design in Table 2.

Table 2. Research Design

Class	Pretest	Treatment	Posttest
Experiment	O_1	X	O_2
Control	O_1	--	O_2

Information:
O_1 = Pretest
O_2 = Posttest
X = Autograph-assisted realistic mathematics education approach (ARME)
-- = conventional approach

5.2. Interaction between Learning Approach and IMA to MPSA

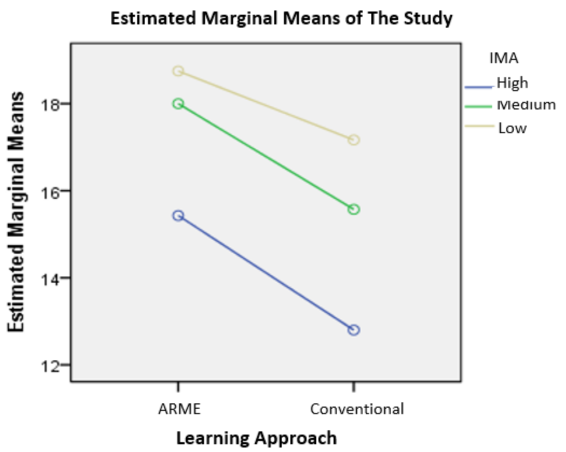

Figure 2. MPSA of the Students based on Learning Approach and IMA

Test of interaction between learning factors and IMA factors was carried out using two-way ANOVA. The test results at the alpha level of 0.05 indicate that there is no significant interaction between the learning approach factors and the IMA factors towards the improvement of MPSA (see Figure 2). That is, there is no simultaneous effect between the learning approach and the IMA on improving student MPSA. MPSA improvement is linear.

5.3. The Process of Solving Mathematical Problems

Based on the mathematical problem solving process, data obtained that the process shown by students in solving mathematical problems is quite varied. One problem solving process for Problem number 2 is presented in the box below.

Problem Number 2

The Math score of all VII grade students in Middle Secondary School 3 is shown in the table. If mode of the data is 83, what is the x-y value? Explain your answer.

Score	Frequency
66 – 70	3
71 – 75	12
76 – 80	x
81 – 85	36
86 – 90	24
91 – 95	
96 – 100	9
Total	120

One example of student answers to problem number 2 is given by the experimental class is displays below.

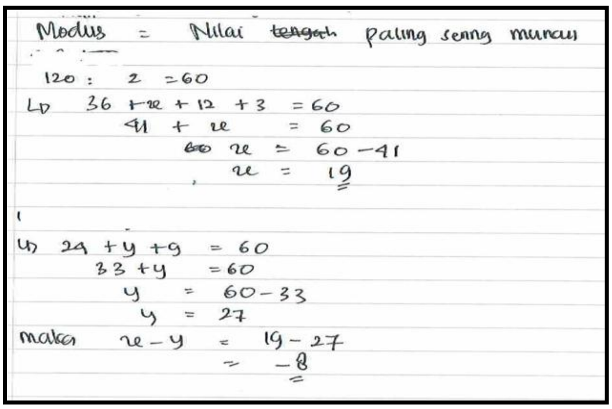

Figure 3. Student Answer for Problem 2

From the example of solving the mathematical problem number 2, it can be seen that this student is wrong in using mathematical symbols. He no longer remembers that writing mathematical ideas into algebraic equations correctly, and interpreting the tables into mathematical ideas is still wrong. In group work, these students are indeed less active so that their learning outcomes are not optimal.

Although still low, for problem number 2, the ARME class obtained test results that were better than conventional class. The average MPSA scores for both classes were 1.97 and 1.12 respectively on scale 4. Overall, the achievement of the MPSA of the experimental class students was higher than that of the MPSA in the control class, but not satisfactory enough (see Table 1). This is presumably because the study time is too short so it does not significantly change in students' learning habits (from passive learning students to active learning students as required in ARME. [29].

The aspects of MPSA used in this study consisted of understanding the problem, proposing strategies, implementing strategies, reflecting (concluding the solutions obtained). Analysis of all the results of mathematical problem solving proposed by the students yields the following findings:

a. In experimental class (ARME class):

Only a small number of students are unable to understand the problem, marked by not being able to make pictures, tables and /or diagrams to help them solve mathematical problems. A small number of students are still not able to plan problem solving, marked by solving problems that are still try and error and guessing. A small number of the student unable to conclude the solution according to the initial problem because of forgetting (accustomed to not making it when solving routine problems).

b. In conventional class:

Almost all of the students is unable to understand the problem, marked by not being able to make pictures, tables and or diagrams to help them solve mathematical problems. A great number of the students unable to plan problem solving, marked by solving problems that are still try and error and guessing. All of the students unable to conclude the solution according to the initial problem because it is not used to make it when solving routine problems.

6. Conclusion

Based on some theories, research findings, and research discussions, it can be concluded that:

1. The improvement of mathematical problem solving ability of the students taught Autograph-assisted realistic mathematical approach is higher than the improvement in mathematical problem solving of the students taught through conventional learning approach.
2. There is no interaction between learning approach and IMA of the student on the improvement of mathematical problem solving ability of the students.
3. The process of solving mathematical problems of the students at ARME class is better than that process of the students taught through conventional learning approach.

7. Suggestion

Based on conclusions above, it can be suggested that:

1. Autograph-assister realistic mathematics education approach (ARME) is recommended to be used by mathematics teacher of grade VII in class to improve mathematical problem solving ability.
2. In applying ARME, the teacher must manage time carefully in order to keep in mind the activeness of students in learning should fulfill the proportion of ideal time.
3. To other researchers, this research may be used as a reference to obtain quality results when applying ARME to improve mathematical problem solving ability and to improve other mathematical thinking skills.

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