

Enhancing Ability of Mathematical Discovery using Computer-assisted Instruction of Junior High School Students

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Abstract—This study was motivated by the role of mathematical discoveries in supporting the development of science and technology. On the other hand, there was less attention to mathematical discovery in the school environment. Therefore, students could learn from studying mathematical discoveries by computer-assisted instruction in mathematics learning. The aims of this study were to examine the effect of learning approach and school qualifications and the interaction of two of that of factors to students' ability of mathematical discovery. This was a quasi-experimental research method with the posttest-only design. Based on the data analysis, it can be concluded that the factor of learning approach has no effect on the ability of students' mathematical discovery, and there are effects of school qualifications on the students' ability of mathematical discovery.

Keywords—mathematical discoveries, computer-assisted, learning approach

I. INTRODUCTION

Mathematics, as a field of knowledge, serves various roles in the individual and social developments. In a social environment, an individual needs the ability to cooperate and communicate with others. The cooperation and communication can take the forms of transactions and similar activities that are largely inseparable from mathematics. In addition, mathematics is needed by individuals for their intellectual development. The problem-solving activity in mathematics teaching and learning helps students develop their thinking. The activity will also develop constructive and creative minds. Eventually, it is these processes that will influence students' mental abilities in daily life.

The roles of mathematics in society are observable in the fields of education, economic development, and science and technology. In the field of education, we can see that almost every subject or course requires or involves mathematics learning. In economic development, mathematics supports economics. Mathematics has been frequently applied in business and financial services. Finally, mathematics makes possible the existence of science and technology. It has been adopted into various disciplines, from social to medical sciences. It has also been successfully used in the development of the present century's science and technology advancements, as demonstrated by its application in various fields, starting from biotechnology to planetary exploration.

As a force supporting science and technology, mathematics should be continuously developed in order to meet the needs of human beings for mathematical knowledge. The knowledge is expected to be applied in daily life, either in the daily equipment or technology. Therefore, the world is waiting for inventions in mathematics as an attempt of improving human life. Certainly, the roles of mathematicians become vital in this case, as the more mathematicians there are, the more inventions there will be.

One of the efforts of creating mathematicians is by cultivating and educating future mathematicians in schools. Hence, teachers should improve their roles in creating new inventors in mathematics. Nevertheless, nowadays the majority of teachers tend to merely create students or graduates with limited skills and no insight or experience with mathematical discovery. Furthermore, although some mathematics textbooks provide conjectures in content presentation, the current teaching and learning activities in the schools are perceived by many to have separated mathematics from its special features. The perception is apparent in teachers' decreasing use of mathematical algorithm while explaining mathematics content; as a consequently, students do not learn why mathematics requires conjectures and concepts; they rarely find that definitions, examples, theorems, and proofs are interesting; what the students feel is that mathematics is all about rigid rules and steps [1].

Each student certainly does not necessarily have to be a mathematician or great in mathematics. However, it is necessary that each masters mathematics since an early age in order to face the technological development and the times. Thus, students should be equipped with mathematical discovery ability in order to be able to find patterns in real life, which indeed are dynamic, uncertain, and competitive. By discovering the patterns in their daily lives, students are expected to be able to predict and solve problems which they will be posted with or are currently facing.

Mathematical discovery in classroom teaching and learning is only possible with a proper learning environment at schools. Using of multi-method or multi-strategy, and multimedia or technology are the demands of the curriculum that must be used by teachers in learning activities both school and university level [2]. Moreover, the use of multi-strategy approaches and technology, as required by the national education curriculum, enables mathematical

discovery. Nonetheless, it is common knowledge that there has not been any significant change in instructional strategies. Mathematics teachers, in general, continue to use conventional learning in delivering teaching materials. The majority of them rarely or even never teach by using technology, which means that technology has not been optimally integrated into mathematics teaching and learning. In addition, although some teachers actually have access to computer and software, both in schools and at home, they rarely integrate these technological advancements into teaching and regularly learning [3].

A teacher should have the ability, skill, and creativity to plan and create appropriate teaching and learning activities to facilitate students' mathematical discovery. Creativity can be found in any field of human activity and is naturally possessed by people of all ages. Creativity will be useful in creating discoveries. Discoveries, in turn, can be made by observing patterns, including the ones in the field of mathematics. This is in line with a statement that mathematical realities exist out there and it is our task to find or observe them [4].

The kind of teaching and learning that will facilitate discoveries is one that features activities that enable students to make an observation. The observation is certainly based on assignment and problems with a greater degree of freedom for students to obtain various results or solutions, make mistakes, make an improvement, and make an inference based on the results. One of the alternative learning approaches with that feature is learning with technology. Technology, such as a computer, can be made a medium for mathematical discovery [5].

Technology has had a great impact on today's education. Various types of software and hardware and information and communication technology (ICT) are available for students' teaching and learning process. ICT at least has an impact on school subjects, knowledge, curriculum, experts' working methods, teachers' teaching methods, students' individual and group working methods, and students' learning methods. Eventually, it will impact on teacher's competency and education. Teachers are then demanded to be able to use technology, both in the classroom and in the laboratory [6].

Technology is not a tool to solve all of the problems in education. However, considering the need for proper learning, technology can be integrated into the teaching and learning process to increase students' learning experience and help them improve their conceptual understanding as well as issues important to their subject [7].

One of the technological advancements teachers can use in classroom teaching and learning is computer-assisted instruction (CAI). CAI increases the learning level of students and improves their attitudes toward mathematics compared with traditional instruction [8]. In this CAI, the researcher uses GeoGebra software. GeoGebra is a dynamic mathematics software. It can be used in the teaching and learning oriented at engagement and problems. GeoGebra developer expects that the software can make mathematics more easily understood. The developer also wants to show students that mathematics is something highly useful and interesting. With GeoGebra, students can play with mathematics. They can do something quickly, shift to any point they want, experiment with mathematics, and have better understanding throughout the process. Therefore,

introducing GeoGebra is appropriate to increase teaching and learning quality [9], and it is expected that the software can help improve students' learning outcomes [10]. With GeoGebra, students can see abstract concepts, making the connection, and discovering mathematics [11].

One of the efforts to encourage regular use of mathematics software in classroom teaching and learning is teaching teachers how to use the software [12]. The proper and effective use of computer and its programs in teaching and learning will provide students with many benefits [13]. Nevertheless, the use of the computer will not assist much if the software used is not combined with appropriate teaching and learning methods, such as student-centered learning, active learning method, and learning by discovery, practice, and experiment.

The present research is expected to provide students with new experiences in developing their mathematical discovery ability. Mathematical discovery in this research is made possible through various learning activities, which can be in the forms of activities resulting in concepts, conjectures, theorems, and proofs. Identifying the weaknesses of a theorem, simplifying proofs, creating a new method of proving, and finding a technique to construct a concept, can also be regarded as mathematical discoveries [5].

Guidance, reflection, and reinforcement for students' ideas and hypothesis are also important in addition to positive feedback for students' work. The researcher or teacher should know the right time and situation for students to be provided with guidance or help. Reflection is needed in students' understanding of the materials delivered, and reinforcement is a medium to broaden or deepen students' mastery and knowledge of a certain case. Therefore, this research is an attempt at providing students with new learning experiences in order to help them be creative and make mathematical discovery.

Mathematical discovery requires students' thinking skills. It has to be noted, though, that each student within the same class or even school has a different level of thinking skill. Hence, it is not impossible that students coming from different schools with different classifications will have different levels of thinking skills. This argument is strengthened by the fact that in general schools with higher qualifications will only admit students with higher-level skills; on the other hand, schools with lower qualifications will admit students with lower-level skills.

II. METHOD

A. *The Research Adopted a Quasi-experimental Method with Posttest-Only Design with Nonequivalent Groups*

$$\begin{array}{c} \text{NR X O}_1 \\ \text{NR O}_2 \end{array} \dots$$

Note:

NR = Nonrandom

X = Computer-assisted instruction

O₁ = O₂ = Test of students' ability of mathematical discovery

A quasi-experimental design in this study did not use pre-test. This is due to the possibility that pre-test may affect the

final test results [14]. In addition, tests the ability of mathematical discovery is a type of test that is not unusual for students. Students need to be trained in solving of this type in the learning process. Students in the experimental class were taught with CAI (X), while those in the control class were taught conventionally. At the end of teaching and learning activities, the students from the two classes were given a posttest ($O_1 = O_2$) to measure their ability of mathematical discovery.

The population in this research consisted of the whole seventh grade students of junior high schools in Ternate City, North Maluku, Indonesia. There are 18 schools in Ternate, 9 of which are public schools and the other nine are private schools, with 11 of them accredited "A," and the remaining seven schools accredited "B." From each school level, two schools were then selected to be the sample of this research, by taking into considerations the curriculum implemented in the schools and the computer facilities there. Out of the four selected schools from all levels, 142 students were selected as the research subjects, divided into the experimental class and control class, each with 61 and 81 students, respectively.

Before treatment, a pre-test was given to both experimental and control classes to test students' prior knowledge. Based on data analysis and test results, it was found that there was no significant difference in the prior knowledge of the students in both classes; therefore, both classes were considered appropriate to be made research sample.

The research activities conducted over 12 meetings. The first and the last meeting used for the test, and the second to the eleventh used for activities in the classroom and computer laboratory. Five learning activities carried out in the classroom, and five learning activities carried out in the computer laboratory.

Test of Mathematical discovery Ability was used to find students' mathematical discovery ability that can take the forms of concept, conjecture, theorem, proof, simplification, and method. This test measures students' mathematical discovery in the materials of Triangles and Quadrilateral. The quality of the test of the ability of mathematical discovery was assessed by tree experts. Two of the three assessors stated that the instrument could be used with minor revisions and the other assessor stated that the instrument could be used without revision. Furthermore, the test instrument is tested to 37 students. The results of the analysis of the students' answers show that the four items need to be revised before used to collect data.

III. RESULTS AND DISCUSSION

The average score of students' ability of mathematical discovery in the experimental class was 7.10 with a standard deviation of 4.979. On the other hand, the average score of control class students' prior knowledge was 6.36 with a standard deviation of 4.154. The data indicate that the average ability of mathematical discovery score of students in the experimental class was higher than that of the students in the control class. In the other perspective, in terms of range, the scores in the experimental class were more evenly spread than the scores in the control class. This can be observed from the experimental class' higher standard deviation score than the control class. Considering that the score for prior knowledge is from 0 to 23, the average score

of the experimental class treated with CAI can be categorized into low, and the average score of the class treated with conventional learning can be categorized into very low.

Meanwhile, school qualification or level of accreditation was determined based on a systematic and comprehensive assessment through self-evaluation and external evaluation, the results of which can be made a reference for the school's performance and eligibility. Students from schools with different qualifications are assumed to have different achievements. This assumption is sensible because schools with good qualifications have a good learning environment that will encourage students to improve their learning outcomes. The average of students' ability of mathematical discovery score of 83 students from the school with an "A" accreditation or qualification was 8.61, with a 4.590 standard deviation. On the other hand, the average score of students' ability of mathematical discovery of the 59 students from the school accredited "B" was 3.95 with a 2.655 standard deviation score. It can be inferred that the average of students' ability of mathematical discovery from the school accredited "A" was greater than that of the students from the school accredited "B." The average of students' ability of mathematical discovery scores of students from the school with an "A" accreditation was also more evenly spread. Thus, descriptively, there was a difference in the average scores of students' ability of mathematical discovery between the two schools with different qualifications. The average score of students' ability of mathematical discovery of students from the school accredited "A" was under the criterion of low, while that of students from the school with "B" accreditation score was under the category of very low.

The analysis used to find whether there were interactions among each of the factors and students' mathematical discovery test was the adjusted rank transform test. This is a non-parametric test to find the interactions of the factors under research. Factor A refers to the learning approach, and factor B refers to school qualification. The interaction between the factors of learning approach and school qualification shows that $p\text{-value} < 0.05$. It can be inferred that there was an interaction between the learning approach and school qualification at a 5% level of significance.

The mathematical discovery ability in this research reflects mathematical understanding in four indicators. The four indicators used to measure the mathematical discovery ability are discovering, exploring and interpreting the relations of the characteristics of angles and bisector line in triangles; discovering, exploring, and interpreting the characteristics of midpoints of quadrilateral sides and the figures formed by the midpoints; discovering, exploring, and interpreting relationships of diagonal lines and the area divided by the diagonal in a parallelogram; and discovering, exploring, and interpreting the characteristics of the lines formed based on the relationship among diagonal lines, median line, and parallel lines on the base side of a trapezoid.

Knowledge can and will only be generated from experiences [15]. The efforts of providing experiences with CAI aimed at helping students gain knowledge of mathematical discovery did not meet the expectation. This is probably due to the students' lack of basic mathematical knowledge, such as understanding of symbols and terms.

The prior knowledge of students is an important part of making conjectures with following instructions of the

problems correctly. Some of the students in this research showed that they did not follow the instructions, and some of them had difficulties with the use of tools, such as compass and protractor. Although discovering conjectures is the first stage in mathematics [16], but with limited skills, students will encounter difficulties in making the conjectures.

The findings of this research emphasize students' increasing ability to making simple conjectures. The learning activity was aided with CAI. The technology was used, as it will allow for students to make conjectures and test the conjectures [17]. In addition, mathematics software allows students to solve a problem, do activities with different examples and testing without wasting a lot of time [18]. However, the technology used in this research did not play a significant role in meeting the desired aim, as demonstrated by the fact that there was no significant difference in the mathematical discovery ability of students taught with CAI and those taught with conventional learning.

The mathematical discovery ability of students from schools accredited "A" was significantly different from that of students from the "B" accredited school. The analysis of interaction among factors under research reveals several findings. First, there was a significant interaction between learning approach (CAI and conventional learning) and school qualification ("A" accreditation and "B" accreditation) on students' mathematical discovery ability.

The findings above show that a learning approach or method successfully implemented in a certain place will not necessarily be equally successful or appropriate when implemented in a different school, for a different subject, school, level, and materials. School qualification that is the standard reference of school quality and its students' quality, in fact, proves to be a proper reference because a quality school will have students with good quality.

Finally, it is recommended that researchers interested in research related to technology consider the following things: Firstly, it is important to select a method or approach appropriate for a certain subject and students' ability. This includes identifying students' problems and finding alternative solutions. Secondly, time should be allocated for the activities in the classroom and laboratory. The time spent in the laboratory, for instance, will affect the students' ability to be measured. A learning activity that is entirely spent in front of a computer will affect students' ability and skills in using geometric construction, such as ruler, compass, and protractor. One of the recommendations of the researcher is the need to do research on the impacts of the quantity of time spent for learning in computer laboratory on students' ability or skills in drawing or constructing geometric objects and finding the ideal percentage for the number of hours spent in the computer laboratory and those spent in the classroom, so that students can construct geometric objects well, both using technology and manually.

IV. CONCLUSION

There is a significant interaction between learning approaches and school qualifications on the ability of students' mathematical discovery. Therefore, computer-assisted instruction can be applied in mathematics teaching and learning to enhance their ability of mathematical discovery.

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