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The influence of problem-solving methods on students' mathematics learning outcomes

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ABSTRACT: This study is quasi-experimental research that aims to determine the influence of problem-solving methods on students' mathematics learning outcomes. The teaching method as an independent variable consisted of: 1) problem-solving methods in the treatment group; and 2) a lecture in the comparison group. Students' mathematics learning outcomes were a response variable. The population was all first-class students of SMA Negeri 13 Makassar. A sample of 78 students was obtained using a cluster random sampling technique. The data collection was effected by giving them a mathematics achievement test conducted at the end of the experiment. Data analysis techniques used analysis of variance with one factor. Results of the variance analysis showed that the learning outcomes of students who are taught mathematics through problem-solving method is better than students' mathematics learning outcomes taught through via the lecture method.

Keywords: Methods, problem-solving, lectures, learning outcomes, mathematics

INTRODUCTION

Improving the quality of human resources requires an adequate education, i.e. education based on national development goals. Thus, the educators' understanding of how to train or teach others to innovate remains nascent with regard to effective teaching models and curricula. As educators train the workforce of tomorrow, it is crucial that they understand the situational processes that can engender the creation of innovative ideas to solve complex workplace issues [1].

It has been stated that mathematics, science and technology education are the tools needed to meet developmental goals. To achieve these goals, there should be a deliberate policy to promote and encourage the development of indigenous technology and the application of such to local developmental goals [2]. Mathematics is the basic knowledge required by students to support their learning success in higher education. Mathematics is required by everyone in daily life. Therefore, students need to have enough mathematical knowledge to face the future. In addition, Eze states that mathematics is the study of size, numbers and patterns [2]. Mathematics is the most international of all subjects, as is mathematical understanding. The status of mathematics as a *basic science* or *knowledge base* supports the development of technology. There is no doubt that the role of mathematics is very important for the success of national establishment, and it is supported by the development of science and technology.

High school students are expected to master mathematics. Mathematics is needed by students not only as a means of scientific thinking, but also to develop the ability to think logically. However, students think mathematics is hard. Problem-solving skills develop faster, if the solver gets newer and newer experience with the activity. Students' performance in problem-solving improves, if they repeatedly encounter the same type of problem or if they can make use of their previous experience [3]. In the study, a technique on *how to read textbooks* is required, so that the content of the book being studied is easily understood, both at home and at school. It has been stated that findings have revealed that the causes of student difficulties were text difficulties, unfamiliar contexts in problems and using inappropriate strategies [4]. Finally, it is suggested that teachers help students in teaching them to look for a pattern, draw a picture and reword the solved problems.

On the other hand, the reality is that the results of learning mathematics in secondary schools are still relatively poor. The average of high school students in Makassar in the Mathematics National Examination is 4.68 from an ideal score of 10. It is a matter of particular concern for all parties, especially those who pay attention to mathematics education.

Therefore, it is necessary to improve the learning outcomes of mathematics, especially in secondary education. One attempt is fixing the factors that may affect the results of studying mathematics. In this regard, there are many factors that can affect the results of students' mathematics learning in high school. In this case, it is the problem-solving method. This factor would help to investigate the influence on students' mathematics learning outcomes.

Based on the background that has been mentioned above, the problem in this study is whether the results of the students being taught mathematics through the problem-solving method are better than the results of the students taught mathematics through the lecture method.

THEORETICAL STUDY

Learning Mathematics

Learning is a process that happens unconsciously and is modified by attitudes, skills and knowledge characterised by a change in behaviour. Someone's behaviour changes because of their learning activities, within the family, school and in the community, individually or in groups. In addition, it has been stated that learning is a process of encoding, strengthening and proceduralising knowledge [5]. This process happens gradually. New knowledge will be forgotten (or remain weak enough to stay unused), if it is not practised, and various elements of knowledge compete to be used on the basis of their strength. The representation of knowledge inherent in this kind of model is called a cognitive model, and the approach of using a cognitive model in a tutoring system has come to be called a cognitive tutor. The first tutoring systems built in this way addressed computer programming and mathematics.

Learning is a process of thinking through a certain way or experience and ultimately students' changes in behaviour are relatively permanent. Furthermore, learning is about the important thing: *who we are*; *what we do?*, because it gives one the opportunity to improve the learning process [6]. In human life, the experience of learning process adds to the development, because the development of maturity is not a lesson.

When it is associated with mathematics, learning mathematics is a student experience gained through interaction with mathematics in the context of teaching and learning activities. It cannot be separated from the characteristics of mathematics as a teaching tool. Students can learn and understand mathematics when they first understand the basic concepts of mathematics, ranging from concrete, semi abstract, to the abstract. It is concluded that learning is most efficient, if students master component skills first and subsequently receive scaffolding on how to integrate them into more complex tasks [5].

Mathematics is a teaching subject. The object is in the form of facts, concepts, operations and principles, all of which are abstract. Therefore, studying mathematics requires various psychological activities, such as abstracting, classification and generalisation. Abstracting means understanding the similarity of various objects; classifying means understanding the grouping of various objects based on similarity; and generalising means concluding that an object based on knowledge has been developed through specific examples. Mathematics, besides its objects, is an abstract and deductive patterned structure, and it also uses a symbolic language. Thus, learning mathematics means learning to use and manipulate symbols. It should be emphasised that before manipulating symbols, the most important thing is to understand the meaning of the idea that symbolised it.

Mathematics is a tool for resolving the problem, including problems in other sciences. Therefore, mathematics teachers should teach the art of problem-solving. Moreover, it is stated that mathematics, science and technology education is indisputably recognised worldwide as an essential tool for effecting national development [2]. The developed economies of the world, such as Japan, China, Germany and the United State of America have always accorded mathematics, science and technology high priority to the extent that 10% of their enormous gross national product (GNP) is spent on science and technology.

Mathematics Learning Outcomes

In the process of teaching and learning, presentation of the subject matter assigned by the teacher in the classroom is done with the intention of students mastering the subject matter provided. When it is linked to mathematics, the learning outcomes are the result of learning achieved by students after participating in the learning process for a certain time period.

It has been revealed that the number of items to include on any given test is a professional decision made by the teacher based on the number of objectives in the unit, his/her understanding of the students, the class time allocated for testing and the importance of the assessment [7]. Shorter assessments can be valid, provided that the assessment includes ample evidence on which the teacher can base inferences about students' scores.

Based on these descriptions, the result of learning mathematics, referred to in this article, are the learning outcomes of high school students in first grade mathematics based on competency standards obtained through the mathematics achievement test.

Learning Mathematics through Problem-Solving

Mathematics problems are a question that go beyond mathematical thinking. When one is faced with a problem, and is not aware of any obvious solution method, one must engage in a form of cognitive processing called problem-solving. Problem-solving is cognitive processing directed at achieving a goal when no solution method is obvious to the problem solver [8].

Solving in mathematics includes understanding the story, solving problems that are not routine, applying mathematics in everyday life or other circumstances, to prove and create. At the same time, since problem solving is a scientific method, it requires the use of critical thinking, the creative and reflecting thinking, the skills of analysis and synthesis [9].

Mathematics problem-solving takes *problem-solving* as cognitive behaviour and *mathematics* as the object being studied. The process of thinking in mathematical problem-solving requires a certain intellectual ability that will organise the strategy pursued in accordance with the data and problems faced. The problem-solving techniques can be defined as the method which is used to get over the hurdles in cases where a solution and a method for solution are not obvious at first [9]. Therefore, it is understood that the acquisition of problem-solving in advance requires mastery of lower cognitive aspects; namely, memory, comprehension and application.

In the process of interaction with a heuristic problem, students generate so-called rules (methods) of preferred searches for its solution. These rules help students attain a subconscious level allowing self-regulation of their activities. In the theory of heuristic teaching mathematics, such techniques are referred to as heuristic methods of general and special types. Both types are the means of a *light-hand* guidance process of problem-solving [10].

Problem-solving is a key subject in standards and focal points. Learning how to solve story problems involves knowledge about semantic construction and mathematical relations, as well as the knowledge of basic numerical skills and strategies. Yet, word problems pose difficulties for many students because of the complexity of the solution process [4]. Polya's stage of conjecture formulation is divided into two stages: search and prediction of patterns, and conjecture formulation [11]. The above stages can be thought of as levels from particular cases to the general case beyond the inductive reasoning process. Not all these levels are necessarily present, there are a lot of factors involved in their reaching.

Based on these descriptions, mathematics education through problem-solving is a way to teach certain topics on a regular basis, when the teacher gives mathematics questions that are problems for students, and the students engage in the step-by-step problem-solving process.

Learning Mathematics through Lectures

In the process of teaching and learning in primary and secondary education, the method that is often carried out by the teacher is lecturing, but sometimes accompanied by questions. It has been stated that the lecture model is a teacher-centred learning model since the teacher is the main information source for lesson materials. Nonetheless, with its one-directional verbal presentation nature, this model is considered suitable for learners with an auditory learning style [12]. It is said that teachers hold an important role and domination in the learning process where they deliver the lesson materials directly to learners.

The lecture method is a method of information delivery in which the teacher speaks actively to provide teaching materials, and students listen or accept it. This method is a form of learning when one-way speakers provide ideas or information, and listeners receive it. In general, definitions and formulae are given and carried out by the teacher. Teachers instruct students in what to do and how to conclude. Example questions are given, then, exercises are given. The processing pattern of teachers is followed carefully by students. Students are simply imitating the way the matter is settled by the teacher.

For example: a mathematics teacher teaching the concept of rational numbers. Before teaching, the teacher prepares teaching materials or materials on rational numbers, then, talks about these numbers in front of the class and the students listen to what the teacher has said. After talking about the material (including sample questions), the teacher gives exercises to the students. As has been expressed by Debora, the performance of teachers in performing the tasks ranging from planning, implementation and assessment of learning outcomes is an illustration of the ability or competence of teachers in curriculum, mastery of the material in lesson planning, and teaching skills of teachers in the implementation of learning, to evaluate the ability of the teacher in the learning outcomes of students [6]. Based on these descriptions, learning mathematics through lectures is a method often used by mathematics teachers, the lecture method or methods are used by teachers in general.

RESEARCH METHOD

This research was based on a quasi-experimental design with one factor. The problem-solving method was used in a treatment group, while the lecture method in a comparison group. Mathematics learning outcomes were the response variable.

The study population comprised first-grade students of SMA Negeri 13 Makassar. Students in grade I-1 were in the treatment group and students of class I-5 were the comparison group, totalling 78 people obtained by cluster random sampling.

This study aimed to find answers to a range of problems that described earlier in this article. In detail, the purpose of the study was to assess the learning outcomes of students who are taught mathematics through problem-solving methods and those taught through lectures, as well as differences in learning outcomes between the two groups. Data were processed using inferential statistics.

RESULTS

Before doing hypothesis testing research, the sample was tested for homogeneity first. It was intended to determine whether both groups had the same variance or not.

Homogeneity Testing

The hypothesis would be tested as follows:

H_0: $\sigma 11 = \sigma 12$
H_1: $\sigma 11 \neq \sigma 12$

Testing criteria used to reject H_0, if the *p* value < significance level $\alpha = 0.05$ and for other conditions, H_0 is accepted. Based on testing by Levene's test, which is shown in Table 1, *p* value = 0.143 with db = 1/76. It indicates that H_0 is accepted at significance level $\alpha = 0.05$, which means that the variances of both groups are homogeneous. It is concluded that the data used to support the truth of the assumption of random error rate has the same variance.

Table 1. Test of homogeneity of variances

Levene statistic	df1	df2	Sig.
2.185	1	76	0.143

Hypotheses Testing on the Influence of Method Factor

This hypothesis can be written as:

H_0: Mi = 0 for all i.
H_1: Not H_0

Based on the statistical value of the F-test, which is shown in Table 2, $F_0 = 13.721$ with db = 1/76 and *p* value = 0.000, then, H_0 is rejected at confidence level $\alpha = 0.05$. So, it can be stated that the teaching method has a significant influence on the results of students' mathematics learning.

Table 2: Tests of between-subjects effects dependent variable: y.

Source	Type III sum of squares	Df	Mean square	F	Sig.
Corrected model	1169.3	1	1169.3	13.721	0.000
Intercept	232880.1	1	232880.1	2732.715	0.000
Methods of teaching	1169.3	1	1169.3	13.721	0.000
Error	6476.7	76	85.2		
Total	240526.0	78			
Corrected total	7645.9	77			

R squared = 0,153 (adjusted R squared = 0.142)

DISCUSSION

Hypothesis testing results show that teaching method factors have an influence on the results of students' mathematical learning. It is described in detail through the following discussion. In solving problems relating to a matter, which is not routine, basic concepts and more mathematics learning experience, acquired through the process of teaching and learning in the classroom and obtained from the environmental community, are required. Student-centred teaching is a learning process based on the needs and interests of students, so that the student-centred teaching is designed to provide a flexible learning system based on the student's life and learning styles. Teachers do not act as the central provider, but only as a supporter [13].

Abstract mathematics problems in the form of multiple choice questions require a relatively similar mind-set to problem-solving; namely, analytical thinking skills. With these capabilities, the mathematical concepts contained in the question stories that are not routine can be manipulated into a form similar to simpler mathematical models. With a simple mathematical model, students were less likely to make mistakes in the process of problem-solving, as well as in the calculation of results.

The learning came through the lecture method with the provision of abstract mathematics tests with multiple choices to students, allowing students to respond to questions. The lecture method with one-way learning and students passively accepting the teaching material is relatively less associated with the nature of mathematics itself. So, when a matter requires a higher thought process, it is usual that many questions are not answered correctly. Thus, it can be said that the results of the students taught mathematics through the problem-solving method is better than the results of the students taught mathematics through the lecture method. The success of learning can best be achieved if teachers can pick the approaches, models, techniques, good tactics and a diverse range of media that can be tailored to the needs and characteristics of students [14].

Problem-solving methods affect the results of students' mathematics learning or it can be stated that the learning outcomes for the students taught mathematics through the problem-solving method is higher than students taught through the lecture method. A teacher's attitude and the teaching strategies significantly influence educational outcomes [3].

Efforts in Application of Learning Mathematics through Problem-Solving

The results of this study indicate that learning mathematics through the problem-solving method gives better results than learning mathematics through the lecture method. In this regard, the efforts to improve students' mathematics learning outcomes can be reached by learning mathematics through the problem-solving method, which uses adapted teaching materials. It allows this to happen, because learning mathematics through the problem-solving method includes the completion of word problems, applying mathematics in everyday life and proving a theorem.

Learning how to solve story problems involves knowledge about semantic construction and mathematical relations, as well as knowledge of basic numerical skills and strategies [4]. Yet, word problems pose difficulties for many students, because of the complexity of the solution process. Studying with learning experiences that are related to daily life will allow students get interested in studying mathematics, even though they are still using abstract concepts.

In the implementation of learning mathematics through the problem-solving method, the mathematics teacher should consider following some instructions: 1) grouping questions based on the material or a similar process for students to select; 2) mentioning aspects of the most important course; and 3) describing the idea of space not only with words, but also with pictures and models. So, in the process of teaching and learning in high school first grade, if it is possible to teach through the problem-solving method, it is expected that mathematics teachers will do so.

Efforts Application of Learning Mathematics through Lectures

However, the results of this study also indicate that learning mathematics through lectures gives better results than the learning of mathematics through solving mathematics problems based on learning outcomes, in situations when students are given a variety of multiple-choice regular formative tests. In this regard, the efforts to improve students' mathematics learning outcomes can be reached by learning mathematics through lectures with a variety of multiple-choice regular formative tests.

It may happen, because in learning mathematics through lectures, students will generally have experienced the model lesson before entering education at a higher level. It is similar to giving a variety of multiple choice tests. Students have known how to take the tests, but this is experienced only on the test quarter or half of the test. Mathematics teachers are expected to provide formative tests and familiarise students with a variety of usual multiple-choice tests earlier, and not during the final test of a teaching programme.

In the implementation of learning mathematics through lectures, teachers can teach mathematics as much as possible and give examples throughout the topics of mathematical material thoroughly, and also give practice questions that are relevant to teaching materials. Mathematics teachers should be skilled and given time to assemble the usual range of multiple-choice tests, as well as time to spent for doing formative tests adapted to the material and the level of potential distress.

CONCLUSIONS

Based on the results of inferential testing, it can be concluded that the results of the students' mathematics taught through the problem-solving method are better than the results of the students taught mathematics learning through the lecture method. Based on the conclusions, there are some suggestions; namely, that mathematics teachers should practise constructing questions to include problems that are relatively neither easy nor difficult, so that every student can practise, which will foster students' creative thinking.

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BIOGRAPHIES

Baso Intang Sappaile was born in Makassar, Indonesia, in 1958. He received a Bachelor's degree majoring at mathematics from the Faculty of Teacher Training and Exact Sciences at IKIP Ujung Pandang in 1982. His Master's degree from the Mathematics Education Department at IKIP Malang was awarded in 1996 and his doctoral degree is from Educational Research and Evaluation at Universitas Negeri Jakarta (2001). He became a professor in the field of calculus in 2008 at Universitas Negeri Makassar (UNM), Indonesia. He has been a lecturer at UNM since 1987 with the subjects calculus, research methodology and multivariate statistics. He received an award from the President of Indonesia as an Exemplary Lecturer in 1998. He has been the secretary of the UNM Professor Appraisal Team since 2010, a member of the Composing Team: Graduate Competency Standards; Content Standards; Teachers and Educational Standards; Academic Lecturer Standards; and Vocational Lecturer Standards of National Education Standards Agency (BSNP) from 2005 to 2013.

Nurwati Djam'an was born in Takkalasi, Indonesia, in 1984. She received her BEd degree in mathematics education from Universitas Negeri Makassar (UNM), Indonesia, in 2005, a MEd degree in mathematics education from the Surabaya State University (UNESA), Surabaya, Indonesia, in 2007 and PhD degree in mathematics education from Curtin University, Perth, Western Australia, in 2016. Nurwati Djam'an is a lecturer in the Mathematics Department at Universitas Negeri Makassar (UNM). Her teaching interests include teaching and learning mathematics, trends and issues in mathematics education, calculus, discrete mathematics, real analysis and research methods. Her primary research interests are communication in mathematics education, diagnostic testing, realistic mathematics education (RME), social justice in mathematics education and civic mathematics. Inside academia, she has also acted as a trainer in school team workshops for mathematics adaptation module of DBE.