Exploring Prospective Teachers' Relational Reasoning In Mathematics Problem-Solving

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Abstract: This study discusses about the relational reasoning of prospective teachers in solution of mathematics problem. The descriptor including: understanding problems, planning the strategy to solve the problem, doing the strategy to solve the problem, and evaluating the solution. The 100 prospective teachers answered to the questions and a series of semi-structured interviews. The result showed that most prospective teachers who had highly capable can do the four steps in mathematics problem-solving include understanding problems, planning the strategy to solve the problem, doing the strategy to solve the problem, and evaluating the solution.

Keywords: Relational, Reasoning, Prospective teacher, Problem-solving

1. INTRODUCTION

One of the problems of formal education in the school's environment is about learning. The low quality of learning gives impacts on the low quality of human resources produced both in quantity and quality. To create quality learning, the teachers should have the ability to develop learning models following the characteristics of students. They are also required to have creativity and high intelligence to create the existing learning resources and apply it proportionally. If this condition is done well, it will produce a competent teacher. The teachers in the learning process can be done well and can improve student achievement and provide quality human resources. Appropriate to School-Based Curriculum (KTSP) (Depdiknas, 2006). Mathematics is a lesson in the schools which aims to create students have the ability to 1) Understanding the concepts of mathematics, explain the connection between concepts and apply it or algorithms be flexible, accurate, efficient, and appropriate in problem-solving. 2) Using reasoning on patterns and traits, performing mathematical manipulations in generalizing, compiling evidence, or explaining mathematical concepts and questions about it; and 3) Communicating the concepts with symbols, tables, diagrams, or other media to clarify circumstances or problems. Have an appreciation of the usefulness of mathematics in life, which has a curiosity, attention, and interest in learning it, as well as flexible attitude and confidence in problem-solving. The mathematical application is always in every aspect of human life. But there is still the problem in it. Mathematical problem-solving is necessary by reasoning because it is an intellectual activity to conclude whether known and predetermined issues/premises. Based on Indonesian Dictionary Kamus Besar Bahasa Indonesia (2010) reasoning comes from the word "reason" which is defined as an activity that allows someone to think logically. The reasoning is an activity that implies a mental process or mental model that is formed in developing the mind of some fact or principle. There are four principles of reasoning, three Aristotelian principles, and one Leibniz principles: 1) The Principium identity (principle of identity), 2) Principium contradictions (principle contradictions), 3) Principium exclucierterti (principle of exclusion tertii) is the principle of the middle way or there is not the third possibility, and 4) Principium rations sufficient (prinsip cukup alasan). Reasoning has been of interest to cognitive psychologists for many years and research has been driven primarily by attempts to understand basic problem solving in healthy adult humans (Krawczyk, 2012). It is a reasoning that involves similarities relationship between orders that includes how these statements and logical thinking is represented mentally. The various kinds of reasoning related to mathematical problem-solving are relational reasoning. For several decades, there has been a push to advance students' knowledge and abilities in science, technology, engineering, and mathematics (STEM). One capacity that has been linked positively to STEM achievement is relational reasoning, which involves identifying associations between objects, ideas, and situations (Jablansky, Alexander, Dumas, & Compton, 2019). According to (Miller Singley & Bunge, 2014) relational reasoning is a fundamental aspect of psychology. Relational reasoning is the ability to discern meaningful patterns within otherwise unconnected information, is regarded as central to human learning and cognition (Dumas, Alexander, & Grossnickle, 2013; Grossnickle, Dumas, Alexander, & Baggetta, 2016). The cognitive processes involved in relational reasoning have been further identified and specified through investigations of neural processing related to these functions. Notably, the progress in functional brain imaging has enabled the study of higher cognitive reasoning processes. These include studies of deductive reasoning (Goel & Dolan, 2000; Monti, Osherson, Martinez, & Parsons, 2007), analogical reasoning (Bunge, 2004; Green, Fugelsang, Kraemer, Shamos, & Dunbar, 2006; Krawczyk, 2010), as well as neuropsychological studies of problem solving (Goel & Grafman, 1995).

The mathematical problem-solving needs a mathematical ability that is the capacity to perform various mental...
activities, thinking, examine the problem in mathematic problem-solving. While in solving process is influenced by mathematics knowledge. According to (Liljedahl, Santos-Trigo, Malaspina, & Bruder, 2016), there are three kinds of mathematical knowledge such as procedural knowledge, conceptual knowledge, and contextual knowledge. The conceptual knowledge is related to mathematical concepts. It builds a cognitive system needed for algorithm formation. The procedural's knowledge is the knowledge of how to perform a mathematical procedure or algorithm. It is contributed to understanding mathematical objects. The contextual knowledge is concerned with the ability to understand contextual problems that include the capacity to identify mathematical concepts in contextual problems, modeling problems, and problem-solving mathematically, to being able to translate mathematical solutions into real solutions according to the context of real problems. According to (Polya, 1981) there are four stages in problem-solving, with the following steps: 1) Understanding the problem, consisting of stating the problem with the own words, what can be tried, sought or done? What is unknown?, What information is obtained from the problems encountered? If there is a problem, what information is not available or not needed? 2) Planning for problem-solving can do by searching for patterns, testing related issues and determining the same techniques which are applicable or not. Testing individual cases or simpler cases of problems encountered to obtain a better picture of problem-solving, creating tables, making diagrams, writing an equation, using guess strategies, thinking backward and identifying parts of the overall goal. 3) Implementation problem-solving plan, from this part some things which need to be passed is: doing the strategy as scheduled in the previous stage, performing the inspection on every step which is done intuitively or formally prove and try to work accurately. 4) Re-check the results. Check it on the original problem (in some cases, this need to be verified), interpret the solution in the context of the original problem, is the resulting solution make sense? Is there any other way to solve the problem? And if possible, determine other related issues or problems more commonly with strategies that can be used to work. The previous studies are focused in student relational reasoning. (DeWolfe, Bassok, & Holyoak, 2016) stated that relational reasoning with fractions can establish a relational set that promotes students' tendency to model relations using algebraic expressions. There is important to study about the relational reasoning in prospective teachers. The aim of this study is to explore and qualitatively describe the relational reasoning profile of female mathematics teachers’ candidates in math problems. The results of this study are expected to be a reference for the lecturers to identify the relational reasoning profiles of students as math teacher candidate and determine solutions in mathematical problem-solving.

2. METHODOLOGY
This type of research uses the qualitative descriptive approach which aims to reveal the relational reasoning profile of female mathematics teacher’s candidates who are highly capable of mathematical problem-solving. The subject is a student of Mathematics Department who has high ability. Instruments are used to collect data in this study consists of two kinds, namely the main instrument and supporting instruments.

2.1 Main Instrument
The researcher is the main instrument (principal instrument). They are the planner, the implementer of data collection, analysis, interpreter of data, and eventually become the reporter of research results. Their activities have full started from the preparation of instrument, data gathering to report writing. Theirs role as the main instrument is to control all process of data collection. The main data needed in this study is qualitative data, namely data to reveal the relational reasoning profile of mathematics teacher candidates in math problem-solving. To obtain the data, it is necessary depth interview on the subject.

2.2 Supporting Instrument
In supporting instruments which used include: Mathematical Ability Test (TKM), Problem-Solving Task (TPM), interview guides, audio and audiovisual recording devices. For more details, please follow the description: 1) TKM test using written test, the input questions taken from the standard test of Seleksi Bersama Masuk Perguruan Tinggi Negeri or Joint Admission Selection of State Universities (SBMPTN) in years 2014 and 2015 from the multiple choices test changed into the written exam (descriptive). The questions have adapted with the aim of this study. The selection criteria for the test are (a) selected from the basic skills test and sciences; (b) the matter is according to a logic standard that is decision making. Furthermore, the draft of TKM will validate by Valuator from math expert (academic or lecturer). 2) TPM is used as a supporting instrument to explore the subject's relational reasoning in mathematical problem-solving consists of TPM 1 and TPM 2 with Time Triangulation. Before using in the research, these tasks were validated first by Valuators’ until they were considered feasible for use in the study. The task of mathematics’ solving used in this research is as follows: TPM 1 “A company has a car Mitsubishi, Suzuki and Daihatsu are used to distribute three kinds of foodstuff such as rice, noodles and cooking oil. The Mitsubishi car can carry 19 bags of rice, 10 boxes of noodles and 24 pack of cooking oil. The Suzuki car can take 6 bags of rice, 4 boxes of noodles and 8 packs of cooking oil. Then, the Daihatsu car can carry 11 bags of rice, 6 boxes of noodles and 14 pack of cooking oil. How many times for each car if the company distributes 100 bags of rice, 56 boxes of noodles and 128 pack of cooking oil?” While in TPM 2: “A company has a car Mitsubishi, Suzuki and Daihatsu are used to distribute three kinds of foodstuff such as rice, noodles and cooking oil. The Mitsubishi car able to carry 13 bags of rice, 3 boxes of noodles and 1 pack of cooking oil. The Suzuki car able to carry 3 bags of rice, 1 box of noodles and 3 pack of cooking oil. And The Daihatsu car able to carry 8 bags of rice, 2 boxes of noodles and 2 box cooking oil.” How many times for each car if the company distributes 67 bags of rice, 17 boxes of noodles and 19 pack of cooking oil. The interview guide is used to collect the suitable data based on the research objectives. The interview guidelines have formulated in two forms such as open interviews and auto amnesia, which is a direct answer to the researcher with the subject in face to face. Unstructured, but free, is possible

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between researchers and research subjects involved in the relatively long interaction. The questions can develop during the interview process. To avoid the miss information and to save the validity of data, so it should use recorded during in the research activities whether audio or audiovisual. The procedure of research data collection is a task-based on the interview. The researchers do depth interview to the subject about the completion of the given TPM. The researchers as the primary instrument in the interview process to check the results of each answer in mathematical problem-solving. The data is collected in the micro-teaching laboratory at the University of PGRI Madiun with the time set together among researchers, subjects, and the Head of English Department (Kaprodi). Interviews have conducted twice, and the first interview performed when the subject was working on TPM1. And the second interview had done when the subject was working on TPM2. From the results of the interviews revealed the relational reasoning profiles of mathematics’ teacher candidates in the mathematical problem-solving. The research’s indicator of relational reasoning profile which done by the subjects includes: In the stage of understanding the problem 1) the subject shows the existence of a problem from the matter. 2) The subject knows the relationship of similarity/difference information between ideas/concepts with other ideas/concepts by explaining. 3) The subject can show the existing information on the matter so that can understand the relationship of similarity/difference between ideas/concepts with others. 4) The subject can know what is known and ask for the problem. In the planning phase of problem-solving; 1) Subject can show information to answer the questions. 2) Subjects can name the basic information to respond to the questions too. 3) The subject can plan to solve the problem. 4) Subjects can mention the terms to resolve the issue. 5) The subject can determine the problem-solving plan. At the stage of carrying out the problem-solving plan; 1) the subject can write down what is known of the problem, 2) The subject can determine the completion steps (mathematical model), 3) The subjects can do alternative completion plans too, 4) The subject can solve the problem. In the Re-check / check the results include: 1) the subject can assure of the completion result by checking the work/settlement. 2) The subject can show the result of the work is the answer to the question, 3) The subject may show the relation of each answer which obtained in checking the answers. In the obtaining the valid conclusions, it is necessary to check the credibility of data by triangulation. It is a technique of checking the validity of data that utilizes something else outside of the data as a comparison against to the existing data. According to Sugiyono (2009), triangulation in testing the credibility of data interpreted as an examination of data from various sources, different ways and different times. There are three types of triangulation, namely: (a) source triangulation; (B) method triangulation and (c) time triangulation. The triangulation of this study is the time triangulation by taking data at different times with similar investigative tasks. If the data obtained is not consistent, it needs to repeat until the data consistency can be found. The technique of data analysis in this research is qualitative data analysis, following the concept of (Miles, Huberman, & Saldana, 2014). The activity of qualitative data analysis is done in interactive until completed its data and continuously in every step of research until saturated. The stages in the data analysis carried out in this study include: (1) category/data classification, (2) data reduction, (3) data presentation, (4) interpretation of data, and (5) conclusions.

3. Result

The results of data research have discussed from the written results of the subject, the results of researchers’ observations at the time of subject doing TPM task, and the interview’s result at the time of the subject doing TPM task too. To obtain the credible of data research is done through time triangulation, so the task is given more than once until getting validity data. In this research the task is given twice, that is TPM 1 and TPM 2 are equivalent functions. Data exposure in TPM 1 and TPM 2 from each stage is validated by comparing data of interview result. Based on the results of TPM 1 and TPM 2 at each stage, the subject shows some of the same things, so that the interview data of TPM 1 and the interview data of TPM 2 can be said as valid interview data. Based on the results of data analysis TPM 1 and TPM 2, and then obtained the relational reasoning profile of female mathematics teacher candidate in mathematics problem-solving.

a. The relational reasoning profile of students as mathematics teacher candidates is capable of understanding the problem: 1). the subject sees that there is a problem, namely three different types of cars: Mitsubishi cars, Suzuki cars, and Daihatsu cars. Those cars must distribute a certain amount goods; each car has a certain quota too. The subjects think how many times each car has to carry all the goods. 2) The subject also understands the relationship of similarity/difference/formation between ideas/concepts with other ideas/concepts by explaining. Overall the problem on TPM1, Mitsubishi cars can carry 19 bags of rice, 10 boxes of noodles and 24 pack of cooking oil. Suzuki Car can bring 6 bags of rice, 4 boxes of noodles and 8 packs of cooking oil, and Daihatsu car can carry 11 bags of rice, 6 boxes Noodles and 14 pack of cooking oil. In TPM2, the subject understands the similar problem of Mitsubishi Cars which able to bring 13 bags of rice, 3 boxes of noodles and 1 pack of cooking oil. While Suzuki Car can carry 3 bags of rice, 1 box of noodles and 3 packs of cooking oil, and Daihatsu Car can bring 8 bags of rice, 2 boxes noodles and 2 pack of cooking oil. The subjects can show the information of the problem so that the students can understand the relationship of similarity/difference between ideas/concepts with other ideas/concepts. The subject also shows the correlation between Mitsubishi cars, Suzuki cars and Daihatsu cars with the total amount of goods that must be transported by those cars. In TPM1 the goods are 100 bags of rice, 56 boxes of noodles and 128 pack of cooking oil. The subject makes a mathematical model of a linear equation with three variables. On TPM2 the subject shows the correlation between Mitsubishi cars, Suzuki cars and Daihatsu cars with the total amount of goods that must be transported by those cars. On the TPM2 the goods include 67 bags of rice, 17 boxes of noodles and 19 pack of cooking oil. 4) Subjects can know what is known of the problem, and the subject provides a description based on the problem, namely from the three cars above. Here,
Mitsubishi car must carry 19 bags of rice, Suzuki must carry 6 bags of rice, and Daihatsu Car can take 11 bags of rice, and there are 100 bags of rice which must be transported. How to make those cars handle to carry all the goods? How many times to carry for each car? In subsequent activities, the subject writes what is understood, makes a code, for example, x for Mitsubishi car, y for Suzuki car and z for Daihatsu car. Mathematical problems can be written as follows: 19x + 6y + 11z = 100, 10x + 4y + 6z = 56, 24x + 8y + 14z = 128. On TPM2 can write down about what the mathematical problem understood: 13x + 3y + 8z = 67, 3x + y + 2z = 17, x + 3y + 2z = 19

On completion of TPM1 or TPM2 subject are essentially same. The subject changed the problem into the mathematical model by forming a linear equation of three variables. Subjects write the terms of the variables used for the problem, i.e., x, y, and z are greater or equal to zero and should not be fractions. In the connection between what is known and what is asked, the subject gives a review of the relationship, i.e., how many times each car carries all the goods to be distributed. Each car inflicted x for Mitsubishi car, y for Suzuki car and z for Daihatsu car.

b. The students’ relational reasoning profiles in the planning of mathematical problem-solving are as follows: 1) Subjects can show information to answer questions. From the information, subject incurs (variable) of each car, then made a linear equation. 2) Subjects can mention the basic information to answer the question, how many times the distribution for each car. 3) The subject can plan to solve the existing problems of how many times the car used based on a load of each car and many goods that must be distributed. The subject transformed the problem into a mathematical model of three linear equations of TPM1 and TPM2. Furthermore, the subject search for the value of these variables by elimination with observing and considering which variables should be eliminated (deleted). The subject reduces equations 1 and 2 initially the three variables generated equation 4 and equation 2 with equation 3 generated equations 5. Equation 4 and Equation 5 is a two-variable linear equation. 4) Subjects can specify the terms to solve the problem. The value of the variable must be greater than or equal to zero x, y and z ≥ 0, and the second condition of its variable should not be fractions x, y and z ≠ \( \frac{a}{b} \), with a, b, x, y and z ∈ B (integers). 5) The subject can determine the value of the variables of equation 4 and equation 5 by plotting in various ways. This is seen when subjects are asked to write down a settlement plan and try to solve the problem. The first way by elimination, the second way is substitute from one equation into another, the third way by the next matrix by using the coordinate point. In the activity of planning mathematics’ problem-solving, the subject can determine the linking of each parts from the problem, the requirement must be filled, and other alternatives if the settlement is not found, so the subject can write / resolve the problem according to plan. Figure 1 shows about important requirement in mathematical problem-solving.

c. The relational reasoning profile of students’ in implementing of mathematics’ problem-solving plan

Based on the data of subject activity in implementing the mathematics’ problem-solving plan, the existing problem was converted into a mathematical model in the form of a linear equation of three variables. Next, according to the available information, the first step to see the relationship between the three cars, the carrying capacity of each car, how much goods must be transported from these cars. From the equation, the subject determines how many times each car can distribute all products that exist: 1). Subjects can learn what is known from the problem, by creating the mathematical model, by giving the code to each car e.g. x for Mitsubishi car, y for Suzuki car and z for Daihatsu car. 2) The subject can determine the mathematical model in the linear equation of three variables. In TPM1: 19x + 6y + 11z = 100, equations (1), 5x + 2y + 3z = 28, equations (2) and 12x + 4y + 7z = 64, equations (3). The subject can determine the values of the variables x, y, and z by eliminating equation (1) with equation (2) and generated equation (4), and by eliminating equation (2) with equation (3) generated equation (5) are two linear equations.

\[
\begin{align*}
19x+6y+11z&=100 \quad (1x1) \\
5x+2y+3z&=28 \quad (2x3) \\
15x+6y+9z&=84 \\
4x+2y&=16 \quad (4x2) \\
5x+2y+3z&=28 \quad (2x2) \\
10x+4y+6z&=56 \\
12x+4y+7z&=64 \quad (3x1) \\
12x+4y+7z&=64 \\
-2x&=-8 \quad (5x2)
\end{align*}
\]

From equation (4) and (5) the subject eliminates one of the variables by means of elimination.

\[
\begin{align*}
4x+2z&=16 \quad (4x1) \\
-2x &-2z=-16+0
\end{align*}
\]

The result of elimination about equation (4) and equation (5) is zero and the variables are also lost. Next the subject tried to use the matrix

\[
\begin{pmatrix}
4 & 2 \\
8 & 4 \\
\end{pmatrix}
\]

The final result was not found

In TPM 2: 13x + 3y + 8z = 67, equations (1), 3x + y + 2z = 17, equations (2) and, x + y + 2z = 19, equation (3) in the same way. The first step, the subject eliminates equation (2) with equation (3) and generated equation (4). And the results of elimination equation (1) with
equation (2) generated equation (5) are two linear equations.

\[
\begin{align*}
(2) & \quad 3x + y + 2z = 17 \\
(3) & \quad x + 3y + 2z = 19 \\
(1) & \quad 13x + 3y + 8z = 67 (1x1) \\
(2) & \quad 3x + y + 2z = 17(2x4) \\
(2) & \quad 12x + 4y + 8z = 68 \\
\end{align*}
\]

Subject reduces equation 1 with equation (2) and equation (3). Furthermore, matrix is used.

\[
\begin{bmatrix}
\frac{2}{2} & -2 \\
\frac{1}{3} & \frac{1}{2} \\
\frac{2}{3} & -\frac{3}{2}
\end{bmatrix}
= \frac{1}{2} 
\]

How to eliminate and determination of zero matrixes, the variables are missing, so the next step which does by the subject is the coordinate point by substituting the variable replacement number. The requirement is positive integer number ≥ 0, and it should not be fraction because it relates to how many times and the trip should be doing till the destination. The reason from the subject which is used this step because in the last process cannot be found the solution through the coordinate point. The subject will orbit the number into equation 4 or equation 5, for example, substitution variable x replaced with the number 0 then found the value y, and when the results are substituted the initial equation then found z value. This method is easier, through the coordinate point can be immediately found the final result. 6). Subjects can solve the linear equations of three variables by the alternative from substitution, elimination, and matrix. If those ways are failed then used the way point coordinates. There are result of students’ relational reasoning profiles in mathematical problem-solving through the requirement that write in the Figure 1 above. It can be show in the Figure 2 (TPM1) and Figure 3 (TPM2) below.

The student's relational reasoning profile in reviewing the work on mathematical problem-solving as follows: 1). Subjects can be assured of the result in completion by showing the work/settlement on TPM 1 and TPM 2, that the final value of the work/settlement done by finding the numbers as the alternative variable in three linear equation is right. To prove the belief the subject will substitute the numbers into equations (1), equation (2) and equation (3). If it is appropriate/right, so the numbers are a solution and at the same time will be a solution how many times the transport to deliver all goods that must be distributed from the company. The numbers cannot be problem-solving if the result is inappropriate/incorrect. 2). Subjects can show the results of the work as the answer to each question, and it is shown subject to each car how many times the distribution of the existing goods. Subject checking answers, by checking the answer. 3). Subjects can show the correlation of each answer to the answers which is obtained from values x, y, and z. Subsequently, the subject substitutes the result, the original equation and fulfill, this way is done one by one (recalculated). Subjects do the final settlement and can be determined value according to the problem. The subject cannot indicate any other way than knows that knowledge of the subject, the last time of school, and the teacher just teaches the way to substitution, elimination, matrix, and coordinate points. Based on Polya's settlement steps hence generally, relational reasoning model of the student in mathematics problem-solving can be described as follows: Subject after finishing read the problem to understand the problem more, how many times the transports to deliver all goods that must be distributed from the company. Subjects relate some goods which are distributed based on the capability of each car. Next, to the mathematical model Mitsubishi car inflicted x, Suzuki car inflicted y and Daihatsu car inflicted z. The symbols/variables are required: the value of the variables x, y and z ≥ 0 and x, y, and z ≠ $\frac{1}{6}$. The meaning of the value x, y, and z are at least 0 (not concerned) and x, y, and z are not fractions because while distribute all goods must reach to the destination and not only in the middle of journeys. The mathematical model is made in linear equations of three-variable that are equations 1, 2 and 3. Furthermore, the subject finds the value of these variables by elimination include considering and paying attention to which variables should be eliminated. The subject reduces equation 1 with equation 2 which originally from three variables produced equation 4 and equation 2 with equation 3 generated equations 5. Equation 4 and Equation 5 is a linear equation of two-variable. Furthermore, from equation 4 and equation 5 in various ways such as elimination, or substitution, or matrix and with coordinate points. By coordinate position (point) and assuming that if the first variable is determined by its positive integer value or its variable is ≥ 0, and it should not be fractional. This activity is repeatedly done by the subject to find the value of the settlement results. In the next activity, the subject should check the result of the work on the completed mathematical problem. The results of the work/completion which do by the subject show that the final value of the work/settlement done by finding the numbers instead of the variables in the mathematical model of the three linear equations is correct. To prove those, in the next step the subject will substitute the obtained numbers into equation (1), equation (2) and equation (3). If it is
appropriate, then the numbers are the settlement and at the same time will be the solution how many times the cars are carrying all the goods that must be distributed by the company. If there is an incorrect number and does not meet the specified requirements, then the numbers are not be a problem-solving. The relational reasoning profile of student’s could describe as a relational reasoning scheme in Figure 4 below.

4. CONCLUSION
This conclusion is based on the results and discussion of the study. The students as mathematics candidates teacher who has highly capable can do the four steps in mathematics problem-solving include understands the problem, plan for problem-solving, carry out a problem-solving plan, and review/recheck the outcome. In understanding the problem, the students are looking at the relationships between issues, which can be used in problem-solving planning. In the implementation of problem-solving, the students do according to plan when making mathematical model, the relationship between linear equations of three variables, determine the conditions that must be met and find the results following the planned. In the step of recheck/check the results of the completion, the students will relate the relationship between the completion result’s with each other. They do calculations by substituting the results into the original equation. The results of this study can be used as an input/reference for lecturers to identify the relational reasoning profiles of students as mathematics teacher candidates on learning and in mathematical problem-solving. When complementing these results, it is necessary to do follow-up research for male students and female students who have high-ability, and male students who have low ability.

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