Adaptive reasoning and strategic competence through problem based learning model in middle school

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Abstract. Most textbooks that are provided by the government employ a lot of non-routine problems in their exercise practice. However, students are incapable of understanding the non-routine problems and they struggle in using their reasoning power which affects the overall achievement of mathematics. The purpose of this study is to identify the students’ ability in relation to adaptive reasoning and strategic competence through Problem Based Learning (PBL) model. This study involved six seventh graders in middle school. Data on students’ adaptive reasoning capabilities and strategic competencies are collected through tests which were conducted over five learning sessions with the PBL model. The research data was analyzed descriptively by comparing test result and interview with the indicator of adaptive reasoning and strategic competences ability. The results show that students’ adaptive reasoning ability can be initiated through learning by PBL model. Two out of the three strategic competence indicators are met by all students. The two indicators are understanding and presenting math problems to verbal forms and selecting the right formula, approach and/or method to solve the problem. Only one indicator of strategic competence is not achieved, which is checking the truth on the settlement of problems that have been obtained. This study provides an overview of the importance of training students to answer non-routine problems through learning. It is a challenge for teachers to familiarize students with systematic steps through various strategies that involve reasoning.

1. Introduction

In teaching Mathematics, teachers aim to help students achieve certain mathematical skills. Therefore, teachers need to design learning activities that enable students to build their abilities. Activity that builds the students’ ability can be done through giving non-routine problem. Non-routine problems are issues that do not use the usual steps, procedures, and algorithms to solve them. They challenge the students’ mind and are not automatically known how to solve it [1]. Students are trained to understand the problem, practice making connections between concepts or situations and then find the right strategy to solve the problem.

In the activity of understanding and solving non-routine problems, the ability to think logically will be formed. The ability to think logically can be related to the ability to make connections between concepts and situations. Logical thinking can also generate reflective thinking skills, the ability to explain, and the ability to justify. This ability is known as the ability of adaptive reasoning [2]. Adaptive reasoning is the ability to think logically, to estimate answers, to explain the concepts of
Another mathematical competence that students need in solving mathematical problems is strategic competence. This competency helps students apply the right strategy to find solutions to a problem. Strategic competence required students to monitor progress and develop alternative plans if the strategies used are predicted less effective [3]. Strategic competence refers to the ability to formulate, present, and solve math problems. Students need to know various ways and strategies for problem solving. Students also need to know the right strategies to be applied in solving specific problems. After the students are able to formulate the problem, the next step is to represent it mathematically, either in numerical, symbolic, verbal, or graphical form [1]. Strategic competence allows students to formulate, present, and solve problems in a mathematical way. Adaptive and strategic competence is part of math proficiency. Math proficiency consists of conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition [1].

The middle school curriculum of mathematics in Indonesia emphasizes mathematical skills. The teaching and learning process is expected to build students’ mathematical skills through problem solving. Problems that are presented by teachers during the learning process are generally followed to the problems presented in textbooks that are mostly routine. Students struggle when they are asked to solve non-routine problem [4]. Students are incapable of understanding the non-routine problems and they struggle in using their reasoning power and consequently, they cannot formulate, present and solve problems efficiently, precisely, and logically [5,6]. This affects the overall achievement of students.

Observations on the 29 students of class VII showed that most students have had some of the math proficiency which is the conceptual understanding and the procedural fluency. However, these students have low adaptive reasoning and strategic competence abilities. The low ability of adaptive reasoning and strategic competence requires a certain effort to improve it. Students need to be trained to solve non-routine problems that can grow both capabilities. Students should be given the opportunity to accurately represent the problem. Students also need to be trained to understand the situation and the key to a problem so as to determine the core mathematical elements and ignore the irrelevant elements. Students need to be facilitated to create drawings/diagrams, write equations, or create more appropriate forms of representation. Strategic competence can be grown at this stage. The strategic competence in concerned with the understanding of the problem and presenting a mathematical problem in various forms (numerical, symbolic, verbal, or graphical), the capability of choosing the right formula, approach and/or method for solving problems and being able to examine the correctness of the problem solved [2].

The efforts to train students to solve non-routine problems is through mathematics learning which emphasizes non-routine problems with a consideration of mathematical context that is close to the students and can develop students’ reasoning ability [7]. This learning can be implemented through Problem Based Learning (PBL) model. PBL is a learning model in which students are faced with authentic problems so that students can develop their own knowledge, develop high-level skills and inquiry. In addition, this learning activity can establish students’ independence as well as increasing their confidence [8].

PBL connects problems learned at school with things that are in the student’s daily activities [9]. In addition PBL also exposes students to non-routine and unstructured questions so that students are accustomed to solving problems by using their reasoning power [10].

This study examines the capabilities of students’ adaptive reasoning and strategic competence together through learning with the PBL model. This is done with the consideration that every ability in math proficiency is interconnected and mutually supportive of one another [1]. This fact distinguishes this research from previous research that has been done in relation to one of the math proficiency capabilities [11,12]. Therefore, the purpose of this research is to identify the ability of students’ adaptive reasoning and strategic competence through the PBL model.
2. Method
The PBL model of learning was conducted five times and the test was held at the end of the fifth meeting. The study involved 29 middle school students in grade 7 who had a good conceptual understanding and procedural fluency, but the ability of adaptive reasoning and strategic competence is low. The data were obtained based on preliminary tests prior to learning with the PBL model. Furthermore, learning is done by PBL model and then final test and semi-structured interview were conducted. Initial and final tests consist of four items: two items that measure the ability of adaptive reasoning and two other items that measure the strategic competence. The indicators of adaptive reasoning and the strategic competence used in developing the tests refer to indicators presented by Kilpatrick [1].

Semi-structured interviews were conducted to strengthen the test results. Semi-structured interview guidelines are prepared on the basis of the identified indicators. Data analysis was done descriptively by comparing the result of the test and semi-structured interview with adaptive reasoning and strategic competence.

3. Result and discussion
The capabilities of adaptive reasoning and strategic competence as part of math proficiency are an interconnected and mutually supportive ability. Adaptive reasoning holds the key in determining the accuracy of chosen strategy. Meanwhile, strategic competence is needed to monitor progress in obtaining solutions and develop alternative plans if the strategies used are supposedly less effective.

The ability of students’ adaptive reasoning and strategic competence in this research is initiated through learning with PBL model. Indicators of adaptive reasoning ability observed are (i) making guesses, (ii) giving reasons or evidence to the truth of a statement, and (iii) drawing conclusions from a statement. Strategic competence indicators are (i) understanding and presenting math problems to verbal forms, (ii) selecting appropriate formulas, approaches, and/or methods to solve problems, and (iii) examining the correctness of the problems that have been obtained. Here is the ability of students’ adaptive reasoning and strategic competence through learning with PBL model.

3.1. Students’ adaptive reasoning
The results of adaptive reasoning test after performing the learning with the PBL model show that all adaptive reasoning indicators have been achieved by most students. 23 out of the 29 students have met all indicators, while the other six students have met only two indicators, which are making guesses and giving reasons or evidence to the truth of a statement.

Based on the answers given, it shows that the student did not write down the conclusions of the answer he obtained. In addition, there are also students who argue his reason for not writing conclusions is because they do not feel it is important. According to the student, it is important that he has answered correctly, although not writing the conclusion at the end of the answer. This was revealed during the interview.

3.2. Students’ strategic competence
The result of strategic competence test after conducting learning with PBL model shows that two strategic competence indicators are achieved by most students. 25 of 29 students have met the indicators (i) understanding and presenting math problems to various forms verbally and (ii) choosing the right formula, approach, and/or method for solving the problem. No student meets the indicator of truth checking on the solution of problems that have been obtained.

Based on the answer given to the test it seems that no student can check the correctness of the problem that has been obtained. Student is able to correctly answer the question but did not provide answers to questions about the overall conclusions of three questions asked.

3.3. Discussion
Based on the result of the study, it can be seen that learning with PBL model can help developing students’ adaptive reasoning ability. Although not all students could meet all indicators measured, but it appeared that most of students had achieved most of indicators. This is consistent with the opinion
of Forgarty that non-routine problem solving can familiarize the students with the power of reasoning [10]. Similarly to the findings of Merritt that learning with the PBL model effectively fosters students’ learning abilities and helps the retention of knowledge [13]. These results are in line with result obtained by [11,12], where the PBL model can foster students’ ability to reason and increase students’ motivation in problem solving. A likewise results were also found by Ostler who applied PBL at the college level toward the students teacher [3].

Allen found that non-routine problem solving in learning with PBL models can motivate students to identify, examine concepts and principles, and find the right solutions to solve problems [14]. These findings are relevant to the students’ circumstances in this study, where students found solutions based on their own understanding of given problem. However, evident from several students’ answer to the problem of car sales showed that they did not fully understand the mathematical procedures. In other word, when the students wrote down the operation, they omitted the use of parentheses to mark the order of operation. Although they did not write parentheses, but students oould find the exact end result that is 20%. This situation indicated that students could find solutions informally through their understanding of the given problem. They understood which operation needs to be done first but didn’t know how to rewrite it using the correct symbol and order. This finding is in line with [15] expression that grade 7 students are still in transition between the concrete operational thinking stage and the formal operational stage, so that they often use informal thinking in solving their problems.

The results also showed that not all indicators measured could be achieved by the students. Some students did not fulfil the indicator of drawing conclusion from a statement. They did not write down the conclusion because they thought there was no need for it since all the steps to solved the problem and also its answer had been written down clearly. Drawing conclusion in this kind of problem indeed seems easy and not important, but the need of writing conclusion is to help students in more complicated math problem that needs several steps and conclusion to reach the final result.

Another indicator that needs improvement is checking the truth on the solution of problem that has been obtained. Although students were able to answer the previous question correctly, but they are struggling to collect each information in those questions and combined them into a conclusion to check the truth on the solution of the problem. Without this skill, students tends to make mistake on one part which will lead to the wrong answer. In this case there is a need to further the study to develop those indicators that hasn’t been achieved yet.

Indicators of adaptive reasoning and strategic competence ability were measured after the PBL model had been implemented in five meetings. Three results indicated that students need to continue to be familiarized with learning with the PBL model to get maximum results. This is in agreement with [1] who mentioned that it is a necessary habituation for students to build both the mathematical ability. Students need to be given enough time to familiarize themselves in using reasoning abilities through solving problems. Sufficient time is also needed for students to develop their strategic competence.

4. Conclusion
The results of this study indicate that learning with PBL model can foster the ability of adaptive reasoning and strategic competence. Both abilities are developed through the thinking process of students in solving problems presented by the teacher. The problems presented are non-routine problems that are characteristic of problem in PBL learning. This problems challenge the students’ mind and they are not automatically solved but involved several reasoning skills, such as finding out the things being asked, which step needs to be done first, which information relevant to answer the question and also how to read and extract information from a picture or chart. Students are trained to understand the problem, practice making connections between concepts or situations and then find the right strategy to solve the problem. The study also shows that it is necessary to familiarize students with their reasoning skills and strategic competence. Teachers also need to pay attention to the thinking stage of students who are in transition between the concrete operational thinking stage and the formal operational stage.
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