Reconstruction of HOTS problems based on questions in mathematics textbook

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Abstract. The purpose of this research was to reconstruct HOTS questions using questions in mathematics textbooks. The study was conducted used a research and development method. The objects of research and development were questions in mathematics textbooks using in junior high school. The research procedure consisted of collecting and selecting textbooks in mathematics instruction, selecting the topic of the subject, identifying and selecting problems, and reconstructing HOTS items. The item reconstruction phase included expert judgment and field trials. HOTS problem reconstruction was carried out through the improvement of questions in the textbooks so that the answers were not unique; the solution required several mathematical concepts and the use of other knowledge. The results showed that questions in mathematics textbooks could be reconstructed as HOTS questions. HOTS problem reconstruction can be achieved by changing the problem in such a way that it does not have a single solution, using a variety of mathematical concepts and other knowledge.

1. Introduction

The analysis of international research agencies, including TIMSS and PISA, indicate that performance of mathematics students in Indonesia was not at satisfactory level. The results of TIMSS-Trend International Mathematics and Science Study, and PISA- Program for International Student Assessment – provide information that the quality of mathematics education in Indonesia needs to be improved. Since Indonesia participates in both activities, the TIMSS and PISA surveys have shown that Indonesian students have always had low performance. For example, the average TIMSS score of Indonesian students in 2015 was 397 or 44 out of 49 participants [1], while the average PISA score of Indonesian students in 2018 was 379 or 74 out of 79 participating countries [2].

Two domains, subject and cognitive domains are being evaluated in TIMSS assessments. In the cognitive area, it includes the implementation, analysis, evaluation, and creation. The last three of the cognitive known as HOTS components [3]. As with the TIMSS assessment, the PISA also evaluates students' cognitive abilities but at 6 levels. However, the same results show that Indonesian students have difficulty solving problems at levels 4, 5, and 6 [4, 5], which are categorized as HOTS questions. HOTS or Higher-order thinking skills are the ability to think that students need to face the future [6], a period of challenges.

HOTS are skills that are activated when students encounter unfamiliar problems, uncertainties, questions, or dilemmas [6], or any new information. When they encounter these situations, students store them in memory, compile facts, link them to existing knowledge, and develop new strategies to achieve goals or solve the problems they face [7]. Therefore, the development of HOTS for mathematics students

is important in our fast-changing and technological society today [8]. Indonesian students must have HOTS in order to be able to confront the future.

Consequently, the Indonesian government had developed national education standards in order to increase the quality of education. One of the functions of the National Education Standards is to provide a basis for the planning, implementation, and supervision of education in the context of the implementation of quality national education. One of the products produced by the National Education Standards Agency is the standardization of textbooks used for learning, including textbooks for mathematics.

Textbooks are crucial elements of teaching and studying mathematics in the classroom. The textbooks reflect the curriculum for both teachers and students [9]. Textbooks are equally valuable instruments for all classes – for students to learn mathematics and for teachers to plan and teach mathematics lessons [10]. On the other hand, mathematics instruction, based on the K-13 curriculum, seeks to enhance students' higher-order thinking skills (HOTS). Are mathematics textbooks a representation of the K-13 curriculum?

Some studies on mathematics textbooks have been concluded that mathematics learning resources based on HOTS are available in limited number in Indonesia. The student textbooks and student activity sheet used in classroom tends to emphasize the memorization of concepts. Students are not encouraged to think critically and creatively [11]. The majority of mathematics problems on the textbooks related to the ability to apply mathematics formulas, procedures, or algorithms [12, 13]. There have not been enough mathematical problems to encourage students to improve their analytical, evaluative, and creative skills [14]. The textbook, on the other hand, is one of the media for the teaching and learning of HOTS. The more material HOTS is available in a textbook, the greater the possibility of HOTS being educated and taught. [15].

In addition, another study showed that very few of the questions in mathematics textbooks could be classified as HOTS problems. Based on Bloom's taxonomy, less than 10% of problems, both examples, and exercises in the mathematics textbook, can be classified as HOTS problems. Majority of the problems in mathematics textbooks categorized as the lower-order thinking skills – LOTS problems [16]. These textbooks in mathematics trigger students unfamiliar with HOTS problems. The lack of familiarity with and completion of HOTS problems makes it difficult for them to find the correct answer to HOTS problems [17, 18]. In other words, using HOTS problems in an instruction is an effort to improve students' HOTS [19, 20]. The more often HOTS questions are used in instruction, the higher the students' ability to solve HOTS questions.

Based on the previous studies and several other reasons, the quality of problems in mathematics textbooks should be improved. The standard of a question can be enhanced through the modification of existing questions [21]. One of the steps that teachers can be taken is by reconstruction the problems in the textbooks on mathematics.

Can the quality of these questions be enhanced in such a way that they can be classified as HOTS problems? What are the ways to improve the quality of mathematics textbooks, especially the problems in mathematics textbooks which are used for learning? It is, therefore, necessary to carry out further research to improve the quality of the problems in mathematics textbooks so that they can be categorized as HOTS questions.

2. Research Method

The research was conducted using a research and development method. Procedures conducted the research were setting research objectives, collecting and selecting mathematics textbooks, selecting subject topic, choosing problem, reconstructing the problem, expert validation, and field trial. The main procedure of the research presenting in following flowchart (figure 1).

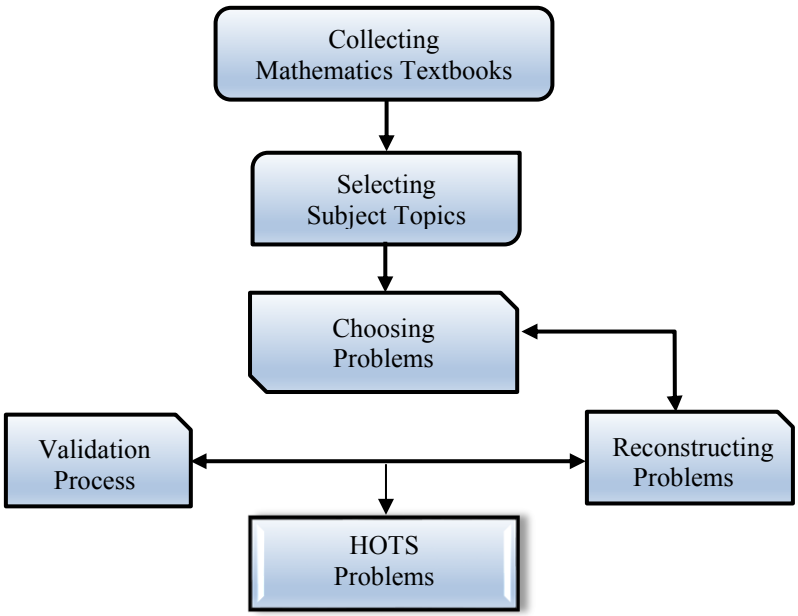

Figure 1. Flowchart of Research Procedure

The objects of the research were mathematics textbook, selected purposively from a number of mathematics textbooks for junior high school. The main criteria used to pick the objects were that they were junior high school mathematics textbooks, which had been certified by the Ministry of Education and Culture, as an official textbook. The textbooks were published by national publishers and used as teaching and learning material in school, with the curriculum K-13.

The next procedure was the topic selection of subjects. The topis selection of subjects from the subject matter to be analyzed was also carried out purposively. The criteria used were none of the questions on the subject that could be classified as HOTS. Examples and exercise issues were the mathematical problems used in this evaluation. The learning topics that were chosen to be used as objects in the study were Number Patterns and Pythagoras Theorem.

The criteria used to reconstruction HOTS questions are the question has non-single answers, and the problem-solving requires a number of concepts. Problems can be addressed in a number of ways was intended for students not to think divergent, but to think convergently. The purpose of using several concepts to solve the problem was to make students use existing knowledge, connect their relationships, and then obtain the solutions. The abilities categorized as Higher-order thinking skills (HOTS).

The final step was the validation process. The problem of HOTS, as a result of the reconstruction, was then qualitatively validated by experts. Experts gave opinions include a refusal clause, in the sense that the problems of reconstruction were not true and cannot be remedied; the reconstructed problems need to be remedied with a few modifications, and the reconstruction is acceptable. Field tests were then carried out to analyze the ability of junior high school students to solve these issues. After that, students were interviewed to understand their way of thought, their thinking trajectory.

3. Results and Discussion

Two questions were developed from the topic of Number Patterns and Pythagorean Theorem in this study. The problems constructed didn't have a single answer and students had to used several previously learned concepts to solved the problem. For the first question, students used different concepts to solved these questions, apart from not being uniquely answered. In the second question, even though the solution was a one-off one, students solved it by using many concepts. They combine some of these concepts, analyze them, and then generate solutions.

3.1. The question has multiple answer

One of the questions was being used as an example for the topic of Number Patterns to reconstruct the problem in a mathematical textbook. The question cannot to be classified as HOTS Problems, for example, as presented in figure 2.

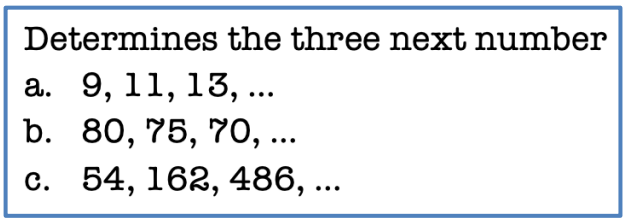

Figure 2. Sample question of Number Pattern from mathematics textbook

Students would easily overcome these problems in Figure 2. They could solve problems without using their higher-level thinking skills. The answer was unique with a certain pattern, so it was classified as a routine question, not a HOTS question. The questions (a) and (b) could be answered by students in less than one minute. But it took them less than 2 minutes to solved part (c) question. The short time taken to solve these problems has shown that students have not used HOTS to solve these problems. This is because these questions are grouped together as routine test.

A routine test is a form of student-familiar problem. In this situation, students did not need high-level thinking skills to solve their problems. Students used only low-level thinking skills to solve problems, i.e. imitative reasoning [22]. Imitative reasoning categorized as low-level thinking skills [23].

During the interview, it was noted that students used a specific algorithm to resolve these problems. First, they paid attention to the number pattern, was there any addition, subtraction, multiplication, or division? They observed, then, how much was the addition, subtraction, multiplication, or division of the number arrangement? The value obtained wss then used to answer these questions.

Moreover, in order to provide HOTS questions on the issue of the Number Pattern, the questions in Figure 2 have been reconstructed as presented in Figure 3.

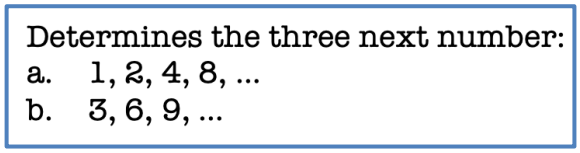

Figure 3. The First sample of reconstructed question

When answering the questions in Figure 3, students were also asked to provide information on how they obtained the answers. The results of the student work for problems in Figure 3 are presented in Figure 4, and 5.

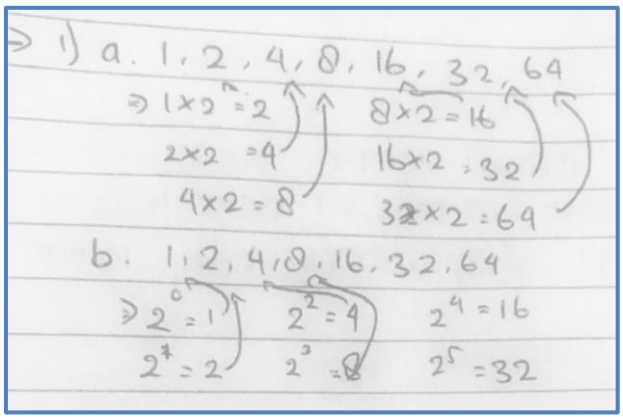

Figure 4. The student solution of problem point (a) in Figure 3.

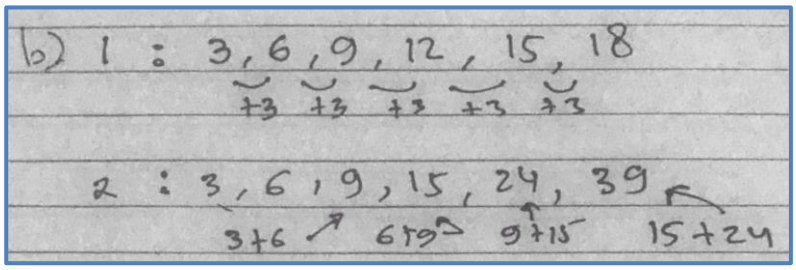

Figure 5. The student solution of problem point (b) in Figure 3.

Figure 4 provided information that the student solves the question in two distinct ways but generates the same answer. On the other hand, it appears in Figure 5 that students had two separate results. What the students did, as seen in the two images, indicates that the reconstructed questions were able to encourage students to think divergent.

Divergent thinking skills are a thought-driven method of seeking solutions, with many alternatives. Divergent thinking is a cognitive ability that has the potential to be used when someone does an action or handles a problem creatively. Creative thinking skills are the HOTS dimension [24].

3.2. The Question using some mathematics concepts and its application

One of the questions was being used as an example for the topic of Theorem of Pythagoras to reconstruct the problem in a mathematical textbook. The question not to be classified as HOTS Problems, for example, as presented in figure 6.

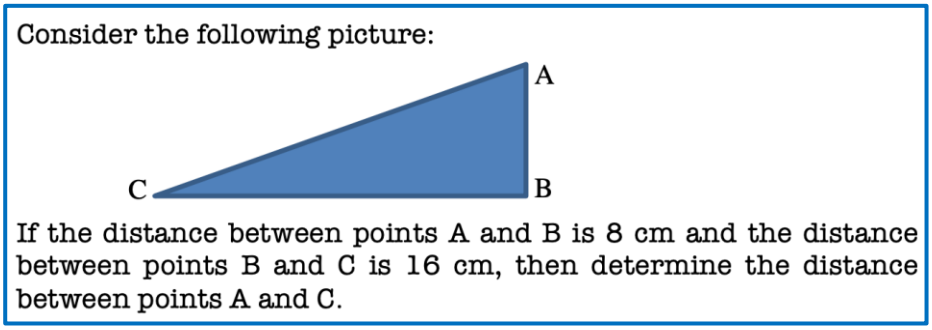

Figure 6. Sample question of Pythagoras Theorem from mathematics textbook

The questions in figure 6 were answered easily. The student used the Pythagoras formula directly to solved the problem. Students only remembered the Pythagorean formula, which was then used to solved the problem. They did not use higher-order thinking skills to solved them. This problem needs to be modified in such a way that it could be used to boost student HOTS, as seen in Figure 7, and the answer is presented in Figure 8.

An observer is 80 m high at the top of the tower. He's seen a ship with an unknown distance. If the base of the tower and the ship are aligned and the area formed by the three places is 6000 m², determine the distance between the observer and the ship.

Figure 7. The Second sample of reconstructed question

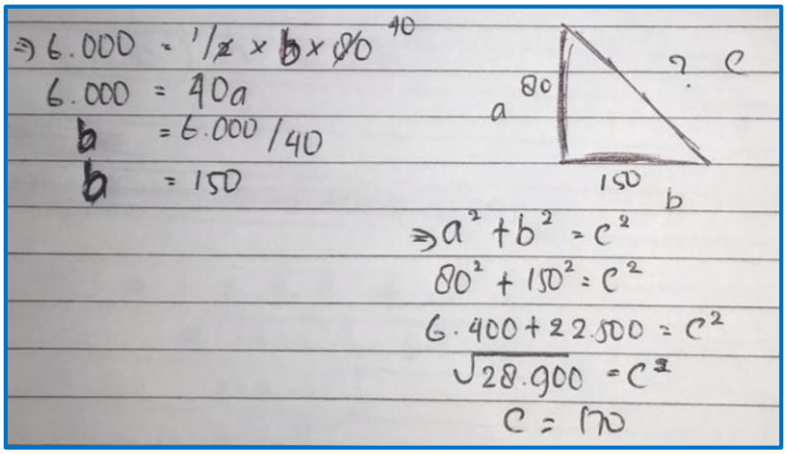

Figure 8. The student solution of Problem in Figure 7.

Figure 8 indicates that students have taken several stages in solving these problems. First, the students were attempting to sketch the pictures from the three locations in question. Second, students used the formula for the triangle area to measure the distance between the base of the tower and the ship. Finally, the students used the Pythagorean formula to solve the problem. Students did not use the Pythagorean theorem explicitly, but used the theory of the triangle to solve the problem. Several ideas have therefore been used to solve these problems, which is one of the characteristics of the HOTS question. [25].

4. Conclusion

The problems in the textbooks of mathematics can be reconstructed into HOTS questions. Reconstruction of the HOTS problem in the textbook of mathematics using two principles. The first criterion for the reconstruction of HOTS questions is that the problems have a non-singular answer, with the purpose of enabling students to use divergent thinking skills. The second principle that questions are constructed requires a number of concepts that students have previously learned to solve these problems. Students will thus be able to use existing knowledge, connect their relationships, and then find solutions. The student abilities were categorized as higher-order thinking skills (HOTS).

Acknowledgment

The authors would like to thank the Faculty of Training and Training at the University of Papua for supporting and funding this research.

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