Students’ thinking process in solving Higher-Order Thinking (HOT) problems through Aptitude Treatment Interaction (ATI) learning model

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Abstract. The assessment model in the 2013 Curriculum has adapted the international standardized assessment model. It is expected to help students to improve their higher-order thinking skills. One of the differences among students that teachers should pay attention to is their thinking process when solving math problems. The Aptitude Treatment Interaction (ATI) learning model is a learning model that adapts learning to the characteristics of students’ abilities. The purpose of this study was to investigate how high-, moderate-, and low-ability students could solve higher-order thinking (HOT) problems through the ATI learning model. This research employed mixed methods. The participants were students of Junior High School 3 Banda Aceh, in which three of them were interviewed. The data were obtained from observations, tests, and interviews. The results showed that the ATI learning model did not directly impact the students’ thinking process in solving HOT problems. Instead, it had a profound effect on students’ activities during the study. The high-ability students were better than the moderate- and low-ability students in each indicator of the thinking process in solving HOT questions. Students’ activities increased during the learning process from the first meeting to the last one.

1. Introduction

Human resources can be improved through the role of education. Mathematics is one of the lessons learned at the formal education level. Mathematics has benefits in human life, underlies the development of modern technology, plays a pivotal role in various disciplines, and advances human thinking [1]. However, mathematics is generally considered a calculated lesson, while mathematicians define calculations as tools in real mathematics. It involves solving math problems and understanding mathematical structures and patterns [2]. The 2013 math curriculum suggests that the goal of mathematics learning is that students have the ability to use mathematics in a reasonable way that can be used for thinking skills.

The 2013 curriculum has adapted an international standardized assessment model to improve students’ higher-order thinking. Crawford and Brown [3] states that high-level thinking is a combination of critical thinking, creative thinking, and basic knowledge thinking. Students’ thinking skills play a pivotal role in understanding and mastering the mathematical concepts they learn. The concept of higher-order thinking (HOT), according to Bloom's taxonomy, was introduced in 1956 in the cognitive domain [4]. Bloom groups intellectual behavior into six levels of thought: knowledge, understanding,
application, analysis, synthesis, and evaluation [5, 6]. However, Anderson and Krathwohl [7] mention that “the domain of cognitive processes included in higher-order thinking is the domain of analyzing, evaluating, and creating.”

In reality, teachers have limited opportunities to engage students in activities that will support the development of high-level cognitive abilities [8]. In addition, Malaysian teachers believe that HOT is only suitable for high-ability students, while low-ability students, who can barely master basic facts, are considered incapable of completing such a task [9]. Such problems are not only found in Malaysia but also in Indonesia. As a result, Indonesian students can only master routine problems, simple computations, and measure knowledge of facts connected to daily life [10].

The results of research on Indonesian students ranging from the Programme for International Student Assessment (PISA), Trends in International Mathematics and Science Study (TIMSS), and Indonesia National Assessment Programme (INAP), showed unsatisfactory results. Students are still weak in high-level cognitive thinking skills, such as reasoning, analyzing, and evaluating [11]. From the above information, it can be said that Indonesian students’ thinking ability is still deficient, especially in mathematics. Such a problem has led to changes in the mathematics learning process in Indonesia. One of the efforts being made by teachers to overcome students’ difficulties in solving math problems is looking at how students think about solving math problems.

Mathematics learning should emphasize students’ thinking process. However, in practice, it still shows procedural, monotonous mathematics learning. Teachers explain the material, give several examples of problems, assign homework to students, and grade students’ work [12]. In this case, the students’ thinking process is often ignored, while it is crucial for them to express their thinking process as they solve math problems. As such, the teachers notice the mistakes that appear in the students’ thinking process. Student individuality is a part or quality of an individual student that consists of interests, attitudes, learning motivations, learning styles, thinking skills, and initial abilities [13].

[14] classifies the thinking process into three steps, namely: 1) The formation of understanding of incoming information through three levels; 2) The formation of opinions, by comparing existing knowledge; and 3) Withdrawal of conclusions, consisting of three kinds: inductive, deductive and analogous conclusions. In general, humans think based on the problem situation. Students use the mental process on their brain in the learning process that reflects the thinking process.

The main part of the thought is the concept [2]. According to Sudjana [15], there are at least six individual differences in students, one of which is intellectual development. The difference among individual students that teachers should consider is the difference in the thinking process when solving math problems. Teachers who teach without considering students’ differences will repeat their explanations when students have not yet understood the lesson and ask questions. Nevertheless, students who have already understood the lesson will get bored with repeated explanations. Conversely, if the teachers do not repeat the explanations, students who slowly catch the lesson will feel sidelined because the learning will be dominated by intelligent students [16]. Therefore, teachers are required to manage the learning process so that all students with different abilities have a desire to learn. One of the actions that teachers can take is to choose the appropriate learning model tailoring to the student’s condition so that the learning atmosphere becomes conducive.

One of the learning models considered to improve students’ activities and learning outcomes is the Aptitude Treatment Interaction (ATI) learning model. Crohnbach [17] argues that ATI is a model that seeks suitable treatments that can be optimally applied to students according to their abilities. ATI is a learning model with several effective learning strategies or treatments used for specific individuals according to their respective abilities [18]. In the learning process, high-ability groups of students are given self-learning. Meanwhile, groups of students with moderate ability are given regular or conventional learning, including preliminary, core, and closing activities. The low-ability groups of students are given the same learning as the moderate-ability students, except for activities in the worksheet. Low-ability groups receive more guidance and assistance from teachers [19]. The steps of the ATI learning model include: 1) measuring each student’s ability (aptitude testing); 2) grouping
students into three groups (high, medium, and low) according to the classification obtained from aptitude-testing results; 3) pretest; and 4) providing treatment.

Several studies were conducted on students’ thinking process, higher-order thinking (HOT), and ATI learning models. For instance, Yee et al. [20] found that no students are considered to have a high level of thinking. Besides, Ayuningtyas and Rahayu’s [21] study revealed that high-, moderate-, and low-ability students meet “evaluate” indicators in solving HOT questions, but some still do not meet other indicators. Meanwhile, Fitasari and Trapsilasiwi [22] pointed out that the Aptitude Treatment Interaction (ATI) learning model improves students’ activities and learning outcomes in the Pythagoras theorem lesson at junior high school levels. However, no research has combined all of the aspects mentioned above.

Therefore, the research questions in this study were: 1) How is the students’ ability to solve higher-order thinking (HOT) questions through the Aptitude Treatment Interaction (ATI) learning model?; 2) How is the thinking process of students with high, moderate and low abilities in solving higher order thinking (HOT) questions through the Aptitude Treatment Interaction (ATI) learning model?; and 3) How are students’ activities during the learning with the Aptitude Treatment Interaction (ATI) learning model?

2. Methods
This study used a mixed-method and sequential explanatory method. The method was sequential if the methods were combined sequentially, quantitative methods in the first stage, and qualitative methods in the second stage. In the first, a quantitative approach was used to look at students' ability to solve HOT questions by applying Aptitude Treatment Interaction (ATI) learning on the cubes and blocks lesson. In the second phase, we used a qualitative approach to describe the students’ thinking process in solving HOT questions and their activities in the learning process through the ATI learning model that contains HOT questions on the cubes and blocks topic. The participants in this study were 22 eighth-grade students of Junior High School 3 Band Aceh of the academic year of 2017/2018. Then, three students taken from high-, moderate-, and low-ability groups were interviewed.

The main instruments in the study were a HOT test, interviews, and an observation sheet of students’ activities. The observation sheet contains 14 aspects, namely: 1) students prepare learning equipment; 2) students question and respond to perception of learning; 3) students notice and listen to the motivation conveyed by the teacher related to cubes and blocks; 4) students pay attention to the teacher’s explanation about the learning objectives and activity plans; 5) students listen to the lesson presented by the teacher; 6) students actively answer the teacher’s questions during the learning process; 7) students actively ask questions; 8) students take a note during the implementation of the ATI learning model; 9) students make groups based on teacher’s instruction; 10) students have conducive discussions during investigation; 11) students organize the data in problem solving given in the worksheet within a specific amount of time; 12) students give presentations and responses during group discussions; 13) students draw a conclusion about the cubes and blocks topics; 14) students and teacher reflect on learning process in solving HOT questions of cubes and blocks topic.

Quantitative data of students’ ability were analyzed descriptively by finding its average and percentage. The data were then analyzed to see how the students’ thinking process in solving higher-order thinking (HOT) questions through Aptitude Treatment Interaction (ATI) learning model. The analysis used indicators adapted from Zuhri (in [23]). The indicators include: 1) state what is known in questions and change them into mathematical expressions; 2) state what is asked in the questions and change it into mathematical expressions; 3) do complete planning; 4) state the steps of problem-solving using the concepts that have been learned; and 5) re-check the solutions being made or correct errors found in each step so that the correct result are obtained. Students' activities during the learning process were analyzed using the data reduction stage, data display, and conclusion drawing or verification.

3. Result and Discussion
Before the learning process with ATI was applied, students took a pretest to categorize their ability. The result showed that, on average, students’ initial ability on block and cube topics is in the moderate category with an average score of 70.91. It was reported that the maximum score of the students was 95, and the minimum score was 50. High-ability students have an average score of 92. Meanwhile, low-ability students have an average score of 57. Based on the ATI learning model, students are grouped based on their abilities: highly-, moderate-, and low-ability groups.

From the pretest results, students were grouped into four groups: (1) one group of high-ability students consisting of four students; (2) one group of moderate-ability students comprising seven students; and (3) two groups of low-ability students with five to six students. Low-ability students are divided into two groups because it is challenging to manage a large group of students. After that, students were treated using an ATI learning model that contained HOT questions for three meetings. At the fourth meeting, students were given a posttest consisting of HOT questions as a learning evaluation. Based on the posttest, it was found that, on average, students’ ability to solve HOT questions through the ATI learning model was 45.18. The score indicated that students were in a low category. The maximum score of students in completing HOT questions is 80. The average score of high-ability students was 69, while that of low-ability students was 35.

After solving HOT questions, one student was selected from each group for an interview. They were asked about their thinking process in solving HOT questions through the ATI learning model. The students being interviewed were those who represented high, medium, and low abilities. The selected students were those who answered all HOT questions and had good verbal communication skills.

The implementation of the ATI learning model in this study had not yet impacted the students’ thinking process in solving HOT problems on cubes and blocks topic. The possible cause is that the level of higher-order thinking ability of students was still low, and they had not yet been familiar with HOT questions (based on the interview with a math teacher taught in the second grade of Junior High School 3 Banda Aceh on November 13, 2019). Similarly, Savitri and Rahaju [23] reported that junior high school students have difficulty solving HOT problems, learning concepts, applying principles, and solving verbal problems.

SM (a high-ability student) met every indicator of the thinking process in the C4 and C5 questions. However, in the C6 question, the student had not yet re-examined the errors correctly from each solution step to obtain the correct results. It can be seen from the interview excerpt with SM as follows.

Researcher : Do you think your answer is correct?
SM : I think it is still wrong, Mam.
Researcher : Do you want to revise it?
SM : Yes, Mam.
Researcher : Ok. You can do it now.
SM : Yes, Mam.
Researcher : What is the result? Can you explain it?
SM : The result is \(1+5+9+13\) and so on plus 4. I use this formula:
\[
S_n = \frac{n}{2}[2a + (n - 1)b]
\]
Researcher : So, What is the result?
SM : It is 5562.
Researcher : Ok. What about the cost or painting fee?
SM : The pattern is 5+16+24 and so on.
Researcher : So, what is the result?
SM : It is 5562.
Researcher : How about the painting fee?
SM : I am confused, Mam. I cannot finish it.

Based on the excerpt above, SM was less able to find the correct answer in Question 3. The student could determine the pattern of arithmetic and the number of unit cubes in building the monument. However, he has difficulty in determining the surface area or the painting cost for the monument. Thus, it can be stated that the student was unable to correct his answer.
The thinking process of students with moderate ability in analyzing (C4), evaluating (C5), and creating (C6) showed that the student was able to state what is known and what is asked in the problem and changed them into mathematical sentences. However, he was less able to make a complete plan and could not find errors from each step. In C4 and C5 questions, the student was less able to state the steps employed to solve the problems by using the concepts that had been studied. Meanwhile, in the C6 question, the student had difficulty in determining the \( n \) in an arithmetic sequence.

On the other hand, the thinking process of students with low ability in analyzing (C4), evaluating (C5), and creating (C6) showed that the student was only able to state what is known and what is asked in the question and change them into mathematical sentences. However, the student could not make a complete plan, state the steps in solving the problem using concepts that have been studied, and re-check the answers or revise the solutions. The interview passage with DM on the C6 question is presented below.

Researcher : From Question 3, what will you do to solve the problem?
DM : I will determine the number of concrete cubes, Mam.
Researcher : How to do it?
DM : I count each level, Mam.
Researcher : Can you explain how many concrete cubes for each level?
DM : At the first level, Mam. I count it from the top.
Researcher : What steps do you use to solve Question 3?
DM : First, I will determine the number of concrete cubes.
Researcher : Then, how to count the total number of concrete cubes?
DM : At the top, there is one. The second has four. The third has eight and up to four.
Researcher : How many are they?
DM : I don’t know, Mam.

Based on the interview above, DM was unable to explain or plan solutions for Question three. He also could not determine the form in the structure of the monument appropriately and analyze the number of concrete cubes in the building monument and the painting cost of the monument. The student was also unable to plan and design a solution for Question 3. The student counted at each level of the monument, but the counting concept was not accurate enough to make a pattern. Then, the student also could not state the number of levels of concrete cubes used in making the monument. Thus, it can be stated that the student was unable to make a complete plan and state the solution steps for the problem using the concepts that have been studied.

This is also in line with the study of Astuti [24] on higher-order thinking skills stating that high-ability students could meet indicators of analyzing, evaluating, and creating. Meanwhile, moderate-ability students were able to meet the indicators of analyzing and evaluating. While low-ability students were only able to meet the indicator of analyzing, and had not been said to meet the indicators of evaluating and creating yet. Besides, the study of Hasyim and Andreina [25] reported that 73% of students’ high-level thinking skills were considered lacking in the evaluation level. The evaluation indicator arises if students can appropriately analyze the problem, understand the intent of the question, and provide appropriate justification and evidence.

Overall, the activities of high-ability students (i.e., SM) were in a good category. The average score of SM's activity at the first and second meetings remained the same (3.7) but increased at the third meeting (3.9). Of the 14 aspects observed, three aspects showed an increase in the third meeting, namely questioning and answering about learning perceptions, the conducive discussion during investigations, and giving presentations and responses during group discussions. The activity of moderate-ability students (i.e., JA) was overall in a good category. While learning in groups, students could do each learning step well. The score of JA’s activity kept increasing from the first meeting to the end. Low-ability students’ activities (i.e., DM), overall, reflected active learning. This can be seen from the learning activities where the low-ability groups could solve the cubes and blocks problems given in the
worksheet. The average score of DM’s activity was not much different from JA’s and SM’s activity score because their scores increased in each meeting.

The results of interviews with the three students also found significant results. The student SM who were in the high group showed interest in learning using the ATI learning model, but the questions given were very difficult and rarely found in learning at schools. Similarly, JA and DM, who were in the medium and low groups, got excited to learn using the ATI learning model as the teacher facilitated the groups. However, JA claimed the questions were highly challenging and barely found in learning at schools. This raised JA’s doubts about his progress in mathematics, especially in solving HOT questions. Meanwhile, DM mentioned a similar statement about the questions and added that students would face difficulty solving the problems if given such a test independently.

The implementation of the ATI learning model influences student activities in the learning process. Consequently, students’ activities were in the very good category in the cubes and blocks lesson. During the learning process, each student played an active role in solving problems given in the worksheet based on their respective groups. The study of Hardiyanto, Abidin, and Fuady [26] found that in the learning process using the ATI learning model on the topic of straight-sided solids, students performed excellent learning activities. Each cycle showed an increase in students’ activities in the learning process. Activities in the learning process with the ATI model provided opportunities for students to explore their abilities as working in their groups using interaction skills and characteristics they had. This study’s findings were also supported by Cronbach and Snow [10] reported that the ATI learning model had an interaction effect or relationship between talents and student characteristics.

4. Conclusion

Students’ ability to solve HOT questions through the ATI learning model was still relatively low, with an average score of 45.18. The students’ maximum score in solving HOT questions was 80, and the minimum score was 25. These data indicated that students still have difficulty in solving HOT questions. The interviews with the three students revealed that they enjoyed learning using the ATI learning model, because the students were assisted by teachers (only for students in moderate and low groups). Nevertheless, the problems assigned have high difficulty levels and are rarely encountered in learning at schools. This raised students’ doubts about their mathematics ability progress, particularly in solving HOT problems.

The qualitative data analysis found that high-ability students could meet every indicator of the thinking process in the C4 and C5 questions. Yet, in the C6 questions, they were less able to re-check their answers or correct each step of the solution to get the correct results. While moderate-ability students were only reached a few indicators of the thinking process. They were less able to make a complete plan and unable to re-check the correct answers or revise the errors found in each step of the solution. While, low-ability students were only able to state what is known and asked in the problem or change them into a mathematical sentence, but unable to make a complete answer and to achieve the thinking process indicator.

Meanwhile, high-, moderate-, and low-ability students’ activities during the learning continued to increase from the first to the last meeting. Therefore, the findings suggest that the ATI learning model actively engaged students in the learning process. However, it did not directly impact the students’ thinking process in solving HOT problems due to their unfamiliarity with the HOT problems in the learning process.

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