Misconceptions of senior high school students in solving high-order thinking skills questions

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Abstract. In the 21st century, the progress of learning mathematics requires students to have high-order thinking skills. In the class, it can be seen that the students high-order thinking skills are still low, which is addressed through the student's difficulties in solving high-order thinking skills questions. One way to find student difficulties is to first analyze the form of misconceptions that students experience when solving high-order thinking skills questions. When the form of misconception can be explained, solutions to develop student's high-order thinking skills will be found. The purpose of this research is to develop high-order thinking skills questions that can diagnose the misconceptions experienced by high school students and to determine the forms of misconceptions high school students in solving high-order thinking skills questions. The form of misconception that is the core of this research is viewed from the learning process of mathematics in the classroom and the ability to solve high-order thinking skills questions. The research method used in this research is qualitative research methods. Research subjects in this study were several high school students in Cirebon. This study uses four high-order thinking skill questions that have been validated by CVR and CVI. This study succeeded in revealing that many students experienced theoretical misconceptions which in students having difficulty changing problems into simpler forms of mathematics. Classification and correlational misconceptions become factors inhibiting students in developing their creating skills. The misconceptions found can be used as a reference for teachers and other researchers in developing mathematics learning based on the abilities and potential of students.

1. Introduction
Education in Indonesia carries out learning reforms through the application of learning and assessment oriented to High-Order Thinking Skills (HOTS). HOTS began to be applied in learning and assessment with the hope that learning mathematics could further encourage the development of thinking skills and creativity of students. HOTS questions have started to be used in national exams starting in 2017, and are increasingly being expanded in the 2018 national exams [1]. However, the application of HOTS questions in 2017 had a significant impact on the decline in the average mathematics score of students on the SMA national exams from all majors.

One of the contributing factors, among others, is that students in Indonesia are less trained in solving contextual problems, demanding reasoning, argumentation and creativity in solving them, where these questions are characteristic of HOTS questions [2] & [3]. This shows that the ability of students in Indonesia in solving HOTS questions is still low. The main purpose of HOTS is to improve students' thinking skills at a higher level, especially those related to the ability to think critically in
receiving various types of information, think creatively in solving problems using their knowledge and make decisions in complex situations [4].

HOTS questions are highly recommended for use in various forms of classroom assessment. HOTS assessment guidelines [5] it is also explained that HOTS questions are assessments based on real situations in everyday life, where students are expected to be able to apply learning concepts in class to solve problems. The explanation above illustrates the importance of student mastery of HOTS questions. However, in practice students in Indonesia are still weak in solving HOTS character problems, especially HOTS math questions. One way to see the location of the problems faced by students in practicing high-order thinking skills is to look at the misconceptions that occur when solving HOTS questions.

Mathematical misconceptions can also be in the form of errors in the application of a rule or inaccurate generalizations [6]. Basically, misconception is different from error. [7] states that an error is an error made by someone due to carelessness, misinterpretation of questions, inexperience in solving questions related to a given topic, or due to the inability to check the answers obtained. Meanwhile, [8] define an error as an error, carelessness, or inaccuracy. It can be concluded that the misconception of mathematics is the understanding of a concept that is not in accordance with the concept (scientific understanding) that has been agreed by mathematicians.

Misconception indicators used in this study are based on the type of misconception described by [9] & [10] misconceptions are divided into three forms, namely theoretical misconceptions, classification misconceptions, and correlational misconceptions. While the HOTS questions used in this study were adapted from [11], [12], & [13] Characteristics of HOTS questions are non-algorithmic, complex in nature, multiple solutions, involving variations in decision making and interpretation, applying multiple criteria, and being effortful in being able to develop higher-order thinking skills including critical thinking and creative thinking. Indicators of HOTS questions compiled based on [14] & [15]. In this study the HOTS question form was taken from research [16] which was combined with a rubric form of misconceptions that might occur when students solve the HOTS questions.

2. Methods
The method used in this research is qualitative method. The essence of this research is to analyze the forms of misconceptions that occur in students when solving HOTS questions which are grouped into three forms of misconceptions, namely theoretical, classificational, and correlational misconceptions. Research subjects in this study were 28 high school students in Cirebon Regency. The test in this study developed HOTS questions by developing three HOTS cognitive levels, namely analyzing, evaluating, and creating. The questions developed are related to skills and knowledge in arithmetic, skills and knowledge in basic algebra, skills and knowledge in advanced algebra, and skills and knowledge in geometry. In order for the test questions to be used in this study, the researcher conducted expert validation. The validation method developed is by using the Content Validity Ratio (CVR) and the Content Validity Index (CVI) [17].

3. Results and Discussion
In this study, the four HOTS questions are related to social arithmetic problems, basic algebra problems, complex algebra problems, and geometry problems. The results of the students' work on the four questions were analyzed based on the form of misconceptions that students might experience. The form of misconceptions experienced by students is described in table 1 below.

| Questions            | Misconceptions of Participants (%) |
|----------------------|------------------------------------|
|                      | Theoretical | Classification | Correlational |
| Arithmetic Problems  | 17.9        | 42.9           | 39.2          |
| Basic Algebra Problems| 28.6        | 50             | 10.7          |
| Complex Algebra Problems| 21.4        | 28.6           | 35.7          |
| Geometry Problems    | 35.7        | 32.1           | 25            |
Based on table 1, there are still students who experience theoretical misconceptions, this proves that there is an inaccurate understanding of a concept that is not in accordance with a concept that has been accepted and scientifically agreed upon by an expert in the field. In addition, students do not understand the necessary and sufficient conditions of a concept [10]. Misconceptions occur when students solve arithmetic problems in figure 1.

Figure 1. Arithmetic Problem

In figure 1, students are asked to estimate one side of the rectangle. The problem can be solved by using the concept of perimeter of a rectangle and relating it to the concept derived from the concept of perimeter of a rectangle. Then students must be able to compile mathematical models related to the concept of inequality to estimate the quantity in question. This problem is presented to determine the ability of students in understanding verbal sentences that contain a mathematical context, then decomposed into a mathematical model. Students experience errors in explaining the key sentence in the problem, namely stating that the length is equal to twice the width.

Figure 2. One Student's Answer to Arithmetic Problems.

Based on Figure 2, it can be seen that students experience a theoretical misconception, where students misread a long sentence from the rectangle which is 2 meters longer than the width to be twice the width. This misconception occurs because students do not master how to make mathematical models from contextual mathematical problems. This is in line with the findings [8] stated that students mistakenly present the concept in other, simpler forms or in the form of mathematical symbols. In addition, there were also correlational misconceptions because students did not relate the problem to the concept of inequality, students always assumed that problems in arithmetic concepts were always related to equations not inequalities. According to [6] mathematical misconceptions can also be in the form of errors in the application of a rule or inaccurate generalizations. This concludes that in a problem students can experience more than one type of misconception.

The next question is given to see the skills and knowledge of students in basic algebra. This question is given to see students' abilities in the sequence of real number operations, as well as to see students' analytical skills in solving problems effectively. The first problem is developed as follows.

Figure 3. HOTS Questions about Basic Algebraic Skills and Knowledge.

In Figure 3, students are required to be able to analyze two numbers presented through real number operations and students are asked to compare the two numbers. In solving these problems students still
experience misconceptions, one of which students experience theoretical and classificational misconceptions. Students are still wrong in calculating real numbers as in Figure 4 (a) below.

![Figure 4. One of the Students’ Answers Solving Basic Algebra problems](image)

Students experience errors in squaring numbers, where students assume that the number being squared will always be positive but does not predict the form of operation it uses. Students experience theoretical misconceptions because they are still wrong in using the sequence of operations on numbers. According to [7] mistakes made by someone due to carelessness, misinterpretation of questions, lack of experience in solving questions related to a given topic, or due to inability to check the answers obtained can be classified as misconceptions. The findings above are consistent with the results of the study. In Figure 4 (b) students do not perform calculations on these two quantities using algebraic manipulation, students use arithmetic aids in solving the problems presented. This is due to the inability of students to analyze the number patterns presented. So that these students experience a classification misconception.

The next problem is to evaluate the form of the algorithm on the concept of inequality. In this problem there is a problem about the sign of inequality which is the result of multiplying by a negative number. However, the form of negative numbers is expressed using algebra so that it demands students' accuracy in evaluating the problem.

The application of algebraic problems makes students give very diverse and unique responses. In the problem, students experience several misconceptions, one of which is the student mistakenly classifies the value \((3 - x)\) as a negative number to serve as a form of evaluation of the problem. Students have not mastered the meaning of sequence properties in real numbers. This error is shown in Figure 5.

![Figure 5. One Student’s Answers Solving Complex Algebra Problems](image)

Based on Figure 5, students experience confusion in understanding the problem. [18] states that a misconception is an understanding of a concept or principle that is inconsistent with the interpretation or generally accepted view of the concept. Therefore, the inconsistent understanding in expressing negative number forms makes students feel confused in evaluating. The form of the symbol of inequality does not seem to have any meaning in the interpretation that the students describe. Even
though the key to evaluating this problem is the multiplication of negative numbers in the form of inequality.

The final problem presented is about the geometry of the plane. Students are asked to compare two components in a picture. The problem presented is related to several things, one of which is the rule of tangents to a circle where the distance of the point of tangency to the center of the circle must be equal to the radius. In other words, the projection of the center point to the tangent to the circle is equal to the radius. In this problem, the students’ theoretical and classifying abilities are very helpful in analyzing the problem. Then use correlational forms so that the problem can be solved.

![Diagram](image)

**Figure 6. One of the Geometry Problems**

Many student responses have difficulty solving problems in Figure 6. One form of problem that occurs is that students use the concept of congruence but are unable to calculate every quantity needed so that students experience theoretical and correlational misconceptions.

![Answer](image)

**Figure 7. One of the Students’ Answers to Solve Geometry Problems**

According to the Figure 7, students assume that the point distance of the point of contact projected onto the side of the rectangle is exactly half its length. This is a form of theoretical misconception experienced by students. Then students use the concept of similarity without connecting the existing rules to the concept. So that students experience misconceptions both theoretically and correlational. In line with states that misconceptions are as inaccurate understanding of concepts, use of wrong concepts, wrong classification of examples, chaos of different concepts and hierarchical relationships of incorrect concepts. This can explain that these students experience misconceptions in solving geometry problems.

4. Conclusion

HOTS problems are made based on four key problems in mathematics, namely arithmetic problems, basic algebra problems, complex algebra problems, and geometry problems. HOTS aspects developed
on these four problems are the ability to analyze, evaluate, and create. Misconceptions from the application of HOTS questions can be identified into theoretical, classification misconceptions, and correlational misconceptions. The results obtained were that the average student experienced many classifications and correlational misconceptions. However, theoretical misconceptions also often appeared in some participants. This indicates that the students' basic math skills are still quite low. The form of misconceptions found is an initial description of students' mathematical abilities and can be used as potential students in learning mathematics, so that teachers have a clear picture before preparing for learning.

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