Characteristics of mathematics high order thinking skill problems levels

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Abstract. There are two levels of thinking skill, namely Low Order Thinking Skill (LOTS) and High Order Thinking Skill (HOTS). Now, many countries believe that HOTS is very important in mathematics education. In Indonesia, the HOTS problems were used in the national exam. The purpose of this study was to construct HOTS problem levels and their characteristics. This research method was literature review. The validity of the results of the study used investigator triangulation involving two experts. For this study, four levels of HOTS were constructed. Each level was combined between the cognitive process dimension of Bloom's taxonomy revised and cognitive domains of Trends in International Mathematics and Science Study (TIMSS) 2015. This paper also presented problems on each level. The teacher can use the results of this study to train students doing HOTS problems by starting from the lowest level.

Keywords: HOTS, mathematics problems, thinking skill, characteristics.

1. Introduction
Mathematics is a very important lesson for education in Indonesia. It can be seen from a fact mathematics is always given starting from elementary school until high school. Ignacio, Blanco Nieto, & Barona [1] state that mathematics learning is a necessity for every individual to develop themselves in today's complex social problems today. Therefore, math can be a tool for solving daily life's problems.

In mathematics education, many daily problems are transformed into mathematical problems. Students are required to solve these problems by mathematical concepts. There are problems that can be converted into mathematical form directly. However, sometimes the problems need deep thinking to be transformed into mathematical forms. Hence, mathematics problems can train various levels of thinking skills.

Due to thinking skills importance and effects in both the teaching and learning processes, the view for curricula shifted from focusing on the knowledge structure to curricula focusing on thinking and dealing with knowledge [2]. In general, there are two levels of thinking skills, named LOTS and HOTS. Wardana defined HOTS as a thinking process that involves mental activities in an effort to explore complex, reflective, and creative experiences that are consciously carried out to achieve goals, named acquiring knowledge that includes the level of thinking (analyzing, synthesizing, and evaluating) [3]. In other hand, Thompson [4] states that LOTS as solving problems with familiar context and situation or apply algorithm already familiar.

Currently, HOTS is considered in education in various countries. In Malaysia, HOTS is implemented in the curriculum because the standard requires students to be able to apply, analyze, assess, and create knowledge through the process of teaching and learning in schools [5]. In Indonesia, HOTS is included...
as problems in the national exam (UN). The Head of the Badan Standar Nasional Pendidikan (BSNP) explains that the assessment of the reasoning model or HOTS was conducted to pursue the backwardness of Indonesian at the international level, especially the results of the Programme for International Students Assessment (PISA) [6]. Competence in PISA mathematics problems is students’ ability to formulate, employ, and interpret mathematics in solving problems [7].

Curriculum 2013 in Indonesia requires students to be able to think and act as creative, productive, independent, collaborative, communicative, and critical. Besides that, the issue of HOTS also can be useful in social life because the problems are based on daily activity. Widana [8] states that the HOTS problem can motivate students to learn as a preparation in social life.

When associated with Bloom's revised taxonomy cognitive level, HOTS was at the level of analyze, evaluate, and create. However, until now, there aren’t level of HOTS. Utemov & Masalimova [9] determine complexity levels but only at the creative mathematical problems. In fact, HOTS levels were important so that problems makers can make HOTS problems with various level of thinking. In addition, it can also be used as a base for determining what problems that suitable for the curriculum or UN.

Ahmad, et al. [10] conduct research to develop instrument of HOTS. Their research also not present level-level of HOTS. In this research, problems HOTS levels are constructed. These levels are based on various references of HOTS problems. Low, Shahrill, Perera, & Prahmana [11] conducted research about characteristics asessment formative practice but not specific in HOTS. Writers, teachers, or e.t.c is expected to be able to use these levels for improving students’ skills in Indonesia in doing HOTS problems.

2. Theoretical Background

2.1. Bloom's Taxonomy Revised

Bloom's taxonomy was firstly introduced by Bloom in 1956. This taxonomy is for classifying objectives and assessment items for the cognitive domain [12]. Bloom introduced six taxonomy levels, named knowledge, comprehension, application, analysis, synthesis, and evaluation.

In 2001, Krathwohl and Anderson revised Bloom's taxonomy. Bloom's taxonomy revised also has six levels. The revised results conducted by Krathwohl and Anderson explain that Bloom's revised taxonomy level were remember, understand, apply, analyze, evaluate, and create.

Remember is the lowest level in the Bloom’s taxonomy revised. Remember was retrieving relevant knowledge from long-term memory [13]. At this level, students only remember their long-term knowledge. At the remembering level, it is divided into two, namely recognizing and recalling.

The second level of the Bloom's taxonomy revised is understanding. Understanding was determining the meaning of instructional messages, including oral, written, and graphic communication [13]. At this level, students do not only remember but also determine the meaning of the message that presented by oral, write, or graphic. The understanding level was divided into seven, namely interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining.

The next level was apply. Apply was carrying out or using a procedure in a given situation [13]. At the apply level, students must be able used formulas to solve problems. This level was divided into two, namely executing and implementing.

The fourth level was analyze. Analyze was breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose [13]. At the analyze level, students do not only required to use one theory, but they must be able to use various related theories. The analyze level is divided into three, namely distinguishing, organizing, and characterizing.

The fifth level of the Bloom's taxonomy revised was evaluate. The evaluate level means making judgments based on criteria and standards [13]. At this level, students are required to think critically by making judgments based on predetermined criteria and standards. This fifth level was divided into two, namely checking and critiquing.

The highest level of Bloom's taxonomy revised was create. Create was putting elements together to form a novel, coherent whole or make an original product [13]. This level of correlation requires students
to be able to construct new things by combining things that already existed before. Creation levels were divided into three, namely generating, planning, and producing.

2.2. Cognitive Dimensions

There are two frameworks assessed in TIMSS 2015, namely the content dimensions and cognitive dimensions. The content dimension determines the subject matter to be assessed, while the cognitive dimension determines the thinking process to be assessed [14]. The cognitive dimensions were used in classifying problems in the textbook. Tan, Ismail, & Abidin [15] research about classification problems with the Malaysia primary four textbook series. The cognitive dimension consists of three things, namely knowledge, application, and reasoning. The following was a description of the three cognitive dimensions.

2.2.1. Knowing

To learn mathematics, the first thing that must be given was knowledge about definitions, symbols, and so on. Students need to be given knowledge about that. Knowledge helps students for solving more complex problems later.

If without knowledge about the basics of mathematics, it was not possible for students use mathematical thinking. One basic example of mathematics was the mathematical language. Mathematics language was very important to know the properties and concepts of mathematics. If students don’t know the mathematical languages, then he difficult building the foundation of mathematics thinking. The IEA [14] construct the characteristics of the knowing that shown in Table 1 as follows.

| Characteristics | Description |
|-----------------|-------------|
| Recall          | Recall definitions, terminology, number properties, units of measurement, geometric properties, and notation (e.g., \(a \times b = ab\), \(a + a + a = 3a\)). |
| Recognize       | Recognize numbers, expressions, quantities, and shapes. Recognize entities that are mathematically equivalent (e.g., equivalent familiar fractions, decimals, and percents; different orientations of simple geometric figures). |
| Classify/Order  | Classify numbers, expressions, quantities, and shapes by common properties |
| Compute         | Carry out algorithmic procedures for \(+, -, \times, \div\), or a combination of these with whole numbers, fractions, decimals, and integers. Carry out straightforward algebraic procedures. |
| Retrieve        | Retrieve information from graphs, tables, texts, or other sources. |
| Measure         | Use measuring instruments; and choose appropriate units of measurement. |

2.2.2. Applying

At this level, students must be familiar with mathematical facts, concepts, and procedures. The applying level requires students to apply their knowledge of facts, concepts, and mathematical procedures. Students are said to be successful at this stage if they succeed representing their ideas in the mathematical thinking.

Problem solving was central to the applying domain, with an emphasis on more familiar and routine tasks [14]. Problems that are solved can consist of various types. Problems in the real world are one example. However, problems also can come from theoretical matters in the fields of geometry, algebra, and etc. The IEA [14] reveals the characteristics of applying as in Table 2 below.

| Characteristics | Description |
|-----------------|-------------|
| Recall          | Recall definitions, terminology, number properties, units of measurement, geometric properties, and notation (e.g., \(a \times b = ab\), \(a + a + a = 3a\)). |
| Recognize       | Recognize numbers, expressions, quantities, and shapes. Recognize entities that are mathematically equivalent (e.g., equivalent familiar fractions, decimals, and percents; different orientations of simple geometric figures). |
| Classify/Order  | Classify numbers, expressions, quantities, and shapes by common properties |
| Compute         | Carry out algorithmic procedures for \(+, -, \times, \div\), or a combination of these with whole numbers, fractions, decimals, and integers. Carry out straightforward algebraic procedures. |
| Retrieve        | Retrieve information from graphs, tables, texts, or other sources. |
| Measure         | Use measuring instruments; and choose appropriate units of measurement. |
2.2.3. Reasoning

In the reasoning domain, logical and systematic thinking is needed [14]. Inductive and intuitive reasoning are based on patterns and regularities that can be used to solve new or unfamiliar problems. These problems can come from the real world and also pure mathematics. Students must transfer knowledge and skills to new situations for solving problems.

Reasoning can be found when students complete unfamiliar or complex problems. However, it is obtained from a mathematical education that can influence the thinking of students to the reasoning domain. One example of reasoning is making a conjecture. It is obtained from logical thinking by conclude from particular rules or assumptions. According to the IEA [14], the characteristics of reasoning are shown in Table 3 below.

### Table 3. The Characteristics of reasoning

| Characteristics       | Description                                                                 |
|-----------------------|-----------------------------------------------------------------------------|
| Determine             | Determine efficient/appropriate operations, strategies, and tools for solving problems for which there are commonly used methods of solution. |
| Represent/Model       | Display data in tables or graphs; create equations, inequalities, geometric figures, or diagrams that model problem situations; and generate equivalent representations for a given mathematical entity or relationship. |
| Implement             | Implement strategies and operations to solve problems involving familiar mathematical concepts and procedures. |

2.3. HOTS

Thinking ability is divided into two, named LOTS and HOTS. According to Fitriani, Windayana, & Jenuri [16], HOTS was the ability to understand and find solutions to a problem in a variety of ways. Abdullah, et al. [17] stated that teacher prepares diverse problems-solving strategies in order to make the students be able to do HOTS problems. While strategies are necessary, students can be activated with developing their mathematical concepts [1].

In the education, HOTS was implemented in the problems. The HOTS type was a measurement instrument used to measure high-level thinking skills, namely the ability to think that is not just recall, restate, or refer without doing processing (recite) [8]. That means the HOTS problems required students can think more than just recall, restate, and recite.

The problems type HOTS can also be linked to the Bloom's taxonomy revised. According to Widana [8], HOTS problems generally measure ability in the analyze, evaluate, and create. The indicators of the HOTS from each of these domains whereas follows.

### 2.3.1. Analyze
Analyze is the fourth level in the Bloom's taxonomy revised. The analyze level becomes the lowest level of the revised Bloom’s taxonomy that is included in HOTS. According to Lewy, Zulkardi, & Aisyah [19] the indicator of the HOTS problem at this level was analyzed incoming information and dividing or structuring information into smaller parts to recognize patterns or relationships, being able to recognize and differentiate the causes and consequences of a complicated scenario, and identifying/formulating problems.

2.3.2. Evaluate
Evaluate is the fifth level in the Bloom's taxonomy revised. This level becomes the second level of the revised Bloom's taxonomy which was HOTS. According to Lewy, Zulkardi, & Aisyah [19] indicators of the HOTS problem at the evaluating level were providing an assessment of solutions, ideas, and methodologies using suitable criteria or existing standards to ensure the value of effectiveness or benefits; make hypotheses, criticize and do testing; and accept or reject a statement based on established criteria.

2.3.3. Create
Create was the highest level of the Bloom's taxonomy revised. Create was also the highest level of the Bloom's taxonomy revised that is included in HOTS. The HOTS indicator at the create level according to Lewy, Zulkardi, & Aisyah [19] is to generalize an idea or perspective on something, design a way to solve problems, and organize elements or parts into new structures that have never existed previous.

3. Research Method
This research method was literature review. The literature review is a surveys scholarly articles, books and other sources relevant to a particular issue, area of research, or theory, and by so doing, providing a description, summary, and critical evaluation of these works [20]. This literature review method was carried out on cognitive levels, both based on Bloom's taxonomy and TIMSS. Data taken from the library includes study of Bloom's taxonomy revised levels, cognitive levels based on TIMSS, and HOTS.

This research aimed to construct the characteristics of HOTS levels. The construction was done by combining the levels of analyze, evaluate, and create on Bloom's taxonomy revised with reasoning domain on TIMSS. After that, the researcher also gave examples of problems at each of the HOTS levels.

This study used investigator triangulation. This triangulation was done by utilizing researchers or other observers for the purpose of rechecking the degree of confidence on the data [21]. Other observers referred in this research were two experts. The first expert was a lecturer in mathematics education and a doctoral degree. The second expert was a writer of mathematics books with master's degrees.

The characteristics of HOTS levels along with the problems at each level were validated by two experts. The validity criteria of the characteristics of HOTS levels and their problems were determined based on what was stated by Hobri [22] as follows. The average value of the validator was denoted by $V_a$. Value of $V_a$ was calculated through equations

$$V_a = \frac{\sum_{j=1}^{n} \sum_{i=1}^{m} V_{ij}}{m \cdot n}$$

with $V_{ij}$ is the value of the $j$ validator and the $i$ indicator, the number of indicators, and the number of validators. The validity criteria are based on the following Table 4.

| Table 4. Validity criteria. |
\[ V_\alpha \]

| \( V_\alpha \) | Validity          |
|----------------|------------------|
| 5              | More Valid       |
| 4 \leq V_\alpha < 5 | Valid           |
| 3 \leq V_\alpha < 4 | Enough Valid    |
| 2 \leq V_\alpha < 3 | Less Valid      |
| 1 \leq V_\alpha < 2 | Not Valid       |

The characteristics of HOTS levels and the problem can be used if the \( V_\alpha \) value is at least valid. However, if there is a revision submitted by the expert, revisions should also be made. If it is not yet in the valid criteria, the characteristics of HOTS levels and their problems must be changed until they reach valid criteria.

### 4. Result and Discussion

Introducing HOTS problems to students was a necessity at this time. Curriculum 2013 requires students to be able to solve HOTS problems. Many HOTS problems in student examinations, one of which in UN.

The teacher must give students HOTS problems regularly to make them familiar with HOTS problems. However, they must be given the lowest level HOTS questions at the beginning in order to their interest to HOTS problems. After they were proficient with the problems, the level of the HOTS problems given must be increased, and etc.

#### 4.1. Characteristics of HOTS Problems Level

In this research, four levels of HOTS were constructed. These HOTS problems leveling was a combination of the level of reasoning and the level of analyze, evaluate, and create from the Bloom's taxonomy revised.

At level 1, the reasoning domain was combined with analyze. This Combining means the problems that include this level were problems in the reasoning domain and require analytical thinking about doing it. Analytical thinking meant individual’s think at the analyze level.

Furthermore, level 2 was a level which was a combination of reasoning domain with evaluate. At this level, the problems were at the reasoning domain and required critical thinking. Critical thinking meant student’s think at the evaluate level to work on a problem.

Level 3 combining the level of reasoning and create. The problems that were included in this level are reasoning problems that required to be able think creatively. Creative thinking means that the individual must think at the creative level to work on the problem.

Finally, level 4 was a combination of levels of reasoning with at least two of analyze, evaluate, and create. The problems included in this level were questions that were at the level of reasoning and required analytical and critical thinking. Moreover, the problems in the reasoning domain with analytical and creative thinking or critical and creative thinking also were included at this level. Characteristics from the four levels can be seen in Table 5.

| Level  | Characteristics                                      |
|--------|------------------------------------------------------|
| Level 1| a) Bringing individuals to be able to analyze        |
|        | information that goes into smaller parts to          |
|        | recognize patterns or relationships.                 |
| Level | Characteristics |
|-------|----------------|
|       | b) Bringing individuals to be able to structure information that goes into smaller parts to recognize patterns or relationships. |
|       | c) Bringing individuals to be able to recognize the causes and consequences of a complicated scenario. |
|       | d) Bringing individuals to be able to distinguish between causes and consequences of a complicated scenario. |
|       | e) Bringing individuals to be able to formulate problems. |
|       | a) Bringing individuals to be able to provide an assessment of the solution with the right criteria to ensure its effectiveness. |
|       | b) Bringing individuals to be able to provide an assessment of ideas with the right criteria to ensure their effectiveness. |
|       | c) Bringing individuals to be able to provide an assessment of the methodology with the right criteria to ensure its effectiveness. |
|       | d) Bringing individuals to be able to make hypothesis. |
|       | e) Bringing individuals to be able to give criticism and judgment. |
|       | f) Bringing individuals to be able to accept or reject according to the criteria set. |
| Level 2 | a) Bringing individuals to be able to generalize ideas. |
|       | b) Bringing individuals to be able to generalize certain perspectives. |
|       | c) Bringing individuals can create a design to solve problems. |
|       | d) Bringing individuals to able to organize elements or parts into new forms that have never been before. |
|       | a) Bringing individuals to be able to formulate questions. |
|       | b) Bringing individuals to be able to provide an assessment of solutions, ideas, or methodologies with the right criteria to ensure their effectiveness. |
| Level 3 | c) Bringing individuals to be able to generalize certain ideas and perspectives. |
|       | d) Bringing individuals to be able to explore experiences in the real world. |
|       | e) Bringing individuals into exploration, discovery, and creation. |
| Level | Characteristics |
|-------|----------------|
| f)    | Bringing individuals to be able to apply the knowledge acquired in the classroom to solve problems in real life. |
| g)    | Bringing individuals to be able to communicate the model conclusions to the conclusion of the problem context. |
| h)    | Bringing individuals to be able to transform concepts of knowledge in class into new situations or contexts. |

The difference in these results with Marzano HOTS [23] was the existence of levels. In the results of this research, level 4 was higher than level 3, level 3 was higher than level 2, and level 2 was higher than level 1. However, on Marzano HOTS [23] no level was given. Likewise, the research by Ahmad et al. [10] only revealed HOTS instruments. Ahmad et al. [10] did not connect one instrument to another as a level. With the level of this research, the teacher can train students to learn HOTS problems in stages.

4.2. HOTS Problems

4.2.1. HOTS Problems Level 1

HOTS level 1 questions must make students be able to do analyzing and reasoning. The following is an example of HOTS level 1 questions.

"There are two positive integers \(a\) and \(b\). If the two numbers are added together, then will be equal to \(c\). Moreover the value \(b = \sqrt{c^2 - a^2}\). Prove that at least one of \(a\) or \(b\) must equal zero!"

In this problem, students were required to analyze information. Furthermore, students must be able to structure the information to recognize the relationship between \(a\), \(b\), and \(c\). Students also must recognize the causal factors which result in at least one of \(a\) or \(b\) being zero.

4.2.2. HOTS Problems Level 2

HOTS level 2 questions must make students be able to do evaluating and reasoning. The following is an example of HOTS level 2 questions.

“A value of \(4^{33}\) can be searched by multiplying the number 4 by 33 times. Determine the most efficient multiplication procedure to calculate the value of \(4^{33}\)!”

This problem brought students to be individual who is critical of a problem. Students are required to find solutions to calculate the value of \(4^{33}\) in the most efficient way. So that, students tried various ways to calculate the value of \(4^{33}\). Moreover, students also must ensure the effectiveness of their method. It was useful to ensure that their solution/way was the most efficient way.

4.2.3. HOTS Problems Level 3

This HOTS level 3 problem is a combination of reasoning and creation, so the problem must also be what makes students be able doing that.

“Siska gets homework to make a miniature garden. The miniature is rectangular with a size 30 cm × 40 cm. Help Siska to determine the building space and its size that can be placed in the miniature garden.”

This problem required students to design a garden miniature with a size limit of 30 cm × 40 cm. In this problem, students were required to creatively put their ideas in designing gardens miniatures. Moreover, students were required to organize what spaces could be placed in the park. Because the park must be attractive, students are also required to be able to arrange the building of interesting spaces in the park. In addition, the size of the building should not exceed the size of a miniature garden.
4.2.4. HOTS Problems Level 4
This HOTS level 4 problem was a combination of reasoning with a minimum of two levels of analyze, evaluate, or create. Therefore, the problem must contain about analyze, evaluate, or create.

"It is known that any ABC triangle with its area is formulated as follows.

a. \[ L = \frac{1}{2} \cdot a \cdot b \cdot \sin \angle A \]

b. \[ L = \frac{1}{2} \cdot a \cdot c \cdot \sin \angle B \]

Investigate whether the two triangle area formulas are true! If it's true, show the proof! If wrong, show where the error is and how to construct the correct formula and the reason!"

This problem required students to be able to give an assessment of the broad formula of a triangle. Students were required to explore each given formula where it is obtained. If the formula is wrong, students must be able to do discovery and creation to determine the correct formula.

4.3. Expert Judgement
This study involved two experts to validate the characteristics of HOTS problem level with the problems. The first expert was a doctor who worked as a lecturer at Universitas Sebelas Maret. The second expert is the author of a math problem book with a master's degree. The assessment of the two experts can be seen in Table 6 below.

| Table 6. Results of expert judgment |
|-------------------------------------|
| Aspects                             | Expert 1 | Expert 2 |
| The language is used in accordance with Pedoman Umum Ejaan Bahasa Indonesia (PUEBI) | 4        | 5        |
| The sentence used is communicative and easy to understand                                      | 4        | 4        |
| The sentences used are not multiple interpretations                                       | 4        | 4        |
| It does not conflict with the existing HOTS theory                                      | 4        | 5        |
| It can be a guideline for conducting HOTS problem leveling                               | 4        | 5        |
| It can be a clue in groups HOTS problems                                                  | 4        | 5        |

From Table 6, we can calculate \( V_\alpha \) as follows.

\[
V_\alpha = \frac{\sum_{j=1}^{n} \sum_{i=1}^{m} V_{ij}}{m \cdot n} = \frac{52}{12} = 4.33
\]

Looks that \( V_\alpha = 4.33 \), so based on Table 4, we could conclude that the characteristics of HOTS problem level with the problems were valid.

5. Conclusion
HOTS question levels are needed so that students are easier to learn HOTS questions slowly. By combining the cognitive level of TIMSS and the revised dimension cognitive process of Bloom's taxonomy, there are four levels of HOTS problems. Each HOTS level has its own characteristics. The characteristics of each level of HOTS questions in this study are declared to be valid by experts. These four levels can be used as a guide by the teacher or writer in teaching HOTS problems to students.

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