Analyzing Students' Higher Order Thinking Skills Using TIMSS-Like Questions

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Abstract. This study aims to assess students' ability in solving Higher Order Thinking Skill (HOTS) problems. Test from national examination, formative and summative test, and also the test written in high school Mathematics textbook commonly used were analyzed, and it found that most of the test are to measure the lower order thinking skills. In 2018, Higher Order Thinking Skill (HOTS) problems emerged in National Examination and bring the nation in polemic about how mathematics classroom should be conducted. This study assess students' abilities in analyzing, generalizing, integrating, justifying, and non-routine problem solving using TIMSS questions. Qualitative method was used as the research approach in this study. The finding showed TIMSS Questions still challenging to students. The findings showed none of the students perceived their thinking skills' levels at "high". 59 students (78.67%) perceived their Higher Order Thinking skills' level at "moderate", while 16 students (21.33%) perceived their Higher Order Thinking skills' level at "low". 78.67% students at "moderate" level has the ability to apply their understanding and knowledge in situation relatively complex.

Keywords: HOTS, Thinking, TIMSS, Higher Order, Bloom Taxonomy

1 Introduction

The Ujian Nasional Berbasis Komputer (UNBK), computer-based national examination in Indonesia, for the Senior High Schoolhas been held on April 2-5 and April 9-12, 2018. Unlike previous years, the UNBKintroduced Higher Order Thinking Ability Thinking Skills (HOTS) problems. The number of problems reaches 10% for Junior High School and 15% for Senior High School. The Ministry of Education and Culture of Indonesia,ensures that HOTS problems will be re-used in 2019 with 20% number of problems (Zunita, 2018).

The implementation of HOTS on UNBK, especially on mathematicswas felt to be too difficult for students. It received a lot of responses from test participants and became viral on social media that makes the KomisiPerlinduganAnak Indonesia (KPAI) criticized the Ministry of Education and Culture's policies (Noor, 2018). In fact, the policy of applying the HOTS model is intended to train children to think critically, creatively, and analytically. This policy in line with the goals ofThe Kurikulum 2013 that stated to improve students' reasoning, including critical and analytical thinking.

BambangSuryadi, Chairperson of the National Education Standards Agency (BSNP) in his presentation said that it had been the policy of the Ministry of Education and Culture to apply mathematical problems that encourage students to do reasoning, not just understanding and applying. Furthermore, the Indonesian National Assessment is directed to an assessment model that requires thinking skills that not only recall, restate, or refer without processing (recite). However, there are HOTS principles that have not been fully implemented in preparing exam questions. In addition, teachers and students are not used to working on HOTS problems even though the problem have long appeared in Mathematics textbooks in schools.Therefore, the application of the HOTS problems in the UN needs to be balanced with an increase in the ability of teachers and students in the teaching and learning process. There have been some training in the preparation of HOTS problems but not regularly and involving many mathematics teachers, especially mathematics teachers in Madrasahs.

In order to encourage the development of the HOTS model, scoring of the questions is done by considering the complexity of the problem. More complex questions are given a higher weight. Thus, there will be distinguishing factors between students who are able to answer the HOTS problems and students who are only

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able to answer easy or moderate problems. So that it is necessary to align the learning process and assessment with reference to national education standards.

There are a number of international tests that are used to evaluating education globally and are also used to find out whether Indonesia is able to compete with countries in the world, and where Indonesia's position is among countries in the world. Two of them are the Program for International Student Assessment (PISA) and Trends in the International Mathematics and Science Study (TIMSS). In this paper, we used TIMSS-like question to analyze the level of students Higher Order Thinking Skill (HOTS). This study aims to assess students' ability in solving Higher Order Thinking Skill (HOTS) problems. Students' abilities in analyzing, generalizing, integrating, justifying, and non-routine problem solving assessed using the TIMSS-like questions.

2 Literature Review

2.1 Higher Order Thinking Skills

Higher Order Thinking Skills (HOTS) are one of the components that are emphasized in the Kurikulum 2013 beside STEM (Science, Technology, Engineering, Mathematics)and 4C (Communication; Collaboration; Critical Thinking and Problem Solving; Creativity and Innovation). However, the implementation is limited to fulfilling the demands of the 2013 Curriculum. Both teachers and students feel that applying HOTS in learning mathematics in schools are challenging. According to Heong (2011), HOTS combines the ability of creative thinking and critical thinking.

Mathematics is a science related to abstract concepts, therefore the presentation of mathematical material in learning is often associated with everyday life with the aim that students are able to find concepts and develop their mathematical abilities based on the experience or knowledge that students have. Students are said to be able to solve a problem if the student is able to examine a problem and be able to use his knowledge into a new situation. This ability is usually known as Higher Order Thinking Skills.

Higher Order Thinking Skills (HOTS) are students' thinking processes at a higher cognitive level which are developed from various cognitive concepts and methods and taxonomy of learning such as; problem-solving methods, taxonomy, and taxonomy of learning, teaching, and assessment. Krulik and Rudnick (1999) explained that HOTS includes the ability to solve problems, the ability to think creatively, think critically, the ability to argue, and the ability to make decisions. While Krathwohl (2002) gives the definition of HOTS as the ability to connect, manipulate, and change the knowledge and experience that has been possessed critically and creatively in determining decisions to solve problems in new situations. Table 1 showed basic concepts of Higher Order Thinking Skill (HOTS) and table 2 showed various meaning on these past year.

Brookhart (also reinforces the above statement stating that HOTS includes logic and reasoning, analysis, evaluation, problem solving, and decision making (judgment). Krathwohl(2002) classifies that judgment is included in the level of evaluation.

In conclusion HOTS is the ability to analyze, evaluate and create in solving problems. Analytical ability can be interpreted as an individual's ability to determine parts of a problem and show the relationship between parts, see the causes of an event or give arguments that support a statement. Evaluation ability is an activity to make judgments regarding the value of an idea, creation, method or method. Creative ability is the ability to combine elements to form a new and unique structure, design ways, and find multiple solutions. Reasoning is a thought process in determining a conclusion from a new knowledge that is received by linking it with the knowledge that has been previously owned. Reasoning is needed in the process of thinking and drawing conclusions in the form of knowledge.

HOTS in mathematics leads formulate, employ, and interpret. These three words describe the process that students must do to connect the context with mathematics and solve it. The capabilities that underlie this mathematical process include communication, mathematics, representation, reasoning and argumentation, formulating strategies to solve problems, using symbolic language, formal, and techniques and operations, using mathematical tools.

Tabel 1. Basic Concept of Higher Order Thinking Skills

Problem Solving (Krulik& Rudnick)	**Taksonomi Kognitif Bloom Original**	**Taksonomi Bloom Revisi (Anderson &Krathwohl)**	**Higher Order Thinking Skill**
Recall Basic	Knowledge	Remember	
	Comprehense	Understand	
	Application	Apply	
Critical	Analysis	Analyze	Critical Thinking
Creative	Synthesis	Evaluate	Creative thinking
	Evaluation	Create	Problem Solving
			Decision Making

Table 2.Various Meaning of HOTS

Sumber	**Tahun**	**Definisi**
King *et al*.	1998	"includes critical, logical, reflective, metacognitive, and creative thinking. Activated when individuals face unknown problems, uncertainties, questions, or dilemmas."
NCTM	2000	"Solving Routine Problems"
Anderson and Krathwohl	2001	Processing –Analyze, Evaluation,
Lopez and Whittington	2001	"(it) happens when someone picks up new information and information stored in memory and relates to and / or rearranges and expands this information to reach a goal or find answers that might be in a confusing situation."
Weiss, E.	2003	Collaborative, authentic, unstructured, challenging problems
Miri*et al*.	2007	"…Strategy - meta-objective setting; while critical, systemic, and creative thinking are tactics - activities needed to achieve the stated goals."
Rajendran, N.	2008	The use of an expanded mind to face new challenges.
Thompson, T.	2008	"Non-Algorithmic Thinking"
Thomas, A. and Thorne, G.	2010	"… (It) requires thinking to a higher level than just restating the facts. (It) requires that we do something with facts. We must understand them, connect them with each other, categorize them, manipulate them, integrate them in new or new ways, and apply them when we seek new solutions to new problems."
Kruger, K.	2013	"involves"concept formation, critical thinking, creativity/ brainstorming, problem solving, mental representation, use of rules, reasoning, and logical thinking

2.2 Trends In Mathematics And Science Study

The assessment of mathematics and science achievements in TIMSS is categorized into two domains; the content and cognitive domain by considering the curriculum that concerned in the country. The distribution of specifications and assessments is as follows:

2.2.1 Contents Domain.

Content consists of four domains: numbers, algebra, geometry, data and opportunities. Each domain of content is detailed in several topics. For example, the domain of number content includes the topic of fractions and decimals, integers, ratios, proportions and percentages. Table 3 shows the proportion of abilities tested in each domain that is assessed on the content dimension.

Table 3. Proportion of Abilities Tested in Content Domain

Domain	Proportion	Topic
Number	30%	Positive Integers
		Fraction, Decimal, and Integer
		Ratio, Proportion, Percentage
Algebra	30%	Algebraic Expression and operation
		Equation and Inequation
		Relation and Function
Geometry	20%	Geometric Shape
		Measurement
Data	20%	Characteristic of Data
		Interpretation Data

2.2.2 Cognitive Domain

Cognitive dimension consists of three domains; knowing, applying, and reasoning. Cognitive dimensions are defined as the expected behavior of students when they are dealing with a mathematical domain that is included in the dimension of content. Table 4 shows the proportion of abilities tested on the cognitive dimensions in the 2015 TIMSS study.

According to taxonomy bloom, the level of high-level thinking ability lies at the level of analyzing (C4), evaluating (C5), and creating (C6). Bloom states that there are two levels of students' mathematical thinking; Lower Order Thinking Skills (LOTS) and Higher Order Thinking Skills (HOTS). Then it can be classified as ability level according to TIMSS and Bloom Taxonomy.

Table 4. Proportion of abilities tested in cognitive domain

Domain	Proportion	Topic
Knowing	35%	Recall
		Recognize
		Classify/Order
		Compute
		Retrieve
Applying	40%	Determine
		Represent/ Model
		Implement
Reasoning	25%	Analyze
		Integrate/Synthesize
Data	20%	Evaluate
		Draw
		Generalize
		Justify

Table 5. Relationship between Bloom Taxonomy, TIMSS, and HOTS

Bloom Taxonomy	**Level TIMSS**	**Level of Thinking Skill**
C6	**Level Advance**	
The ability to combine elements into something new, complete and broad, or make something original	The ability to give reasons, draw conclusions, make generalizations, and solve linear equations. Students can complete various fractions, proportions and percent problems and justify their conclusions. Students can express algebraic generalizations and model situations.	**Higher Order Thinking Skills (HOTS)**
C5		
The ability to determine a degree based on certain norms, criteria or benchmarks	The ability to solve various problems involving equations, formulas and functions.	
	The ability to give reasons with geometry figures to solve problems. The	

Bloom Taxonomy	Level TIMSS	Level of Thinking Skill
	ability to give reasons with data from several sources or unusual representations to solve problems with many steps.	
C4	**Level High**	
The ability to separate concepts into several components and connect with each other to gain an understanding of the concept as a whole	The ability to apply their understanding and knowledge in situation relatively complex. Students can use information fromseveral sources for solving problems involving various typenumbers and operations. The ability to change the form of ordinary fractions into decimal and percent forms or vice versa. The ability to show basic procedural knowledge related to expression algebra. The ability to use line, angle, shape and space to solve problems and analyze data.	
C3	**Level Intermediate**	
Ability to do something and apply concepts in certain situations	The ability to apply basic mathematical knowledge in a variety situation. Students can solve problems involving decimals, fractions, proportion and percentage, and simple algebraic relationships. The ability to make two-dimensional image connections to three-dimensional objects. The ability to read, interpret, and create charts and tables.	**Lower Order Thinking Skills (LOTS)**
C2	**Level Low**	
Ability to understand instructions and affirm ideas or concepts that have been taught	Students have knowledge of integers and decimals, basic calculations and graphs.	
C1		
The ability to recall information stored in memory		

3 Research Method

This study is a survey research where data collected directly from respondents. The data was collected at MAN 1 Takengon, MAN 2 Takengon, and MAN 3 Takengon. The population was the 10^{th}-grade students in Aceh Tengah, Aceh. The students had to be representation of (1)Gender, (2)Level of Achievement, (3) Age $\leq$ 15 years old.

20 TIMSS-like questions were given to 75 students. These questions are designed so that both dimensions of assessment; content and cognitive can be observed. The form of questions in TIMSS is multiple choice with 4 answer choices, short entries and descriptions. Short entries and descriptions are often called "constructed responses". If students answered the

question correctly, they given a score of 2, and if answered incorrectly given a score of 1, and 0 if no answer.

The TIMSS score then assessed based on students ability in analysis, evaluation, and creation (Anderson, 2001). Categorizing and analyzing the level of Higher Order Thinking Skills is the main target of this study.Then, students' answers were analyzed based on Level of HOTS by Anderson and Kratwohl (2011). The HOTS level then categorized as follow:

Table 6. Category of HOTS Level

Mean Score	Level
0.00 – 1.00	Low
1.01 -1.50	Moderate
1.51 – 2.00	High

4 Research Finding

The level of students' Higher Order Thinking Skills (HOTS) were carried out by giving HOTS test questions taken from the questions tested on TIMSS in 2015. The test assessed cognitive domain of each content; number, algebra, geometry, and data and chance. There are 29.37% students who answer the test correctly, 63.93% students have wrong answer, and 6.33% did not answer the test. Percentage of students that answer TIMSS-like questions were given on table 7.

Table 7. Percentage of students that answer TIMSS- like questions

	Correct Answer	Wrong Answer	No Answer
MAN 1 Takengon	27.80%	65.00%	7.20%
MAN 2 Takengon	34.20%	55.60%	10.20 %
MAN 3 Takengon	27.20%	71.20%	1.60%
Average	29.73%	63.93%	6.33%

The findings showed none of the studentsperceived their thinking skills' levels at "high". 59 students (78.67%) perceived their Higher Order Thinking skills' level at "moderate", while 16 students (21.33%) perceived their Higher Order Thinking skills' level at "low".78.67% students at "moderate" level has the ability to apply their understanding and knowledge in situation relatively complex. They able to use information from several sources for solving problems involving various type numbers and operations. They also have the ability to change the form of ordinary fractions into decimal and percentage forms or vice versa. Meanwhile, 16 students at "low" level able to apply basic mathematical knowledge in a variety situation. Students can solve problems involving decimals, fractions, proportion and percentage, and simple algebraic relationships. The students have the ability to make two-dimensional image connections to three-dimensional objects and the ability to read, interpret, and creats and

tables.

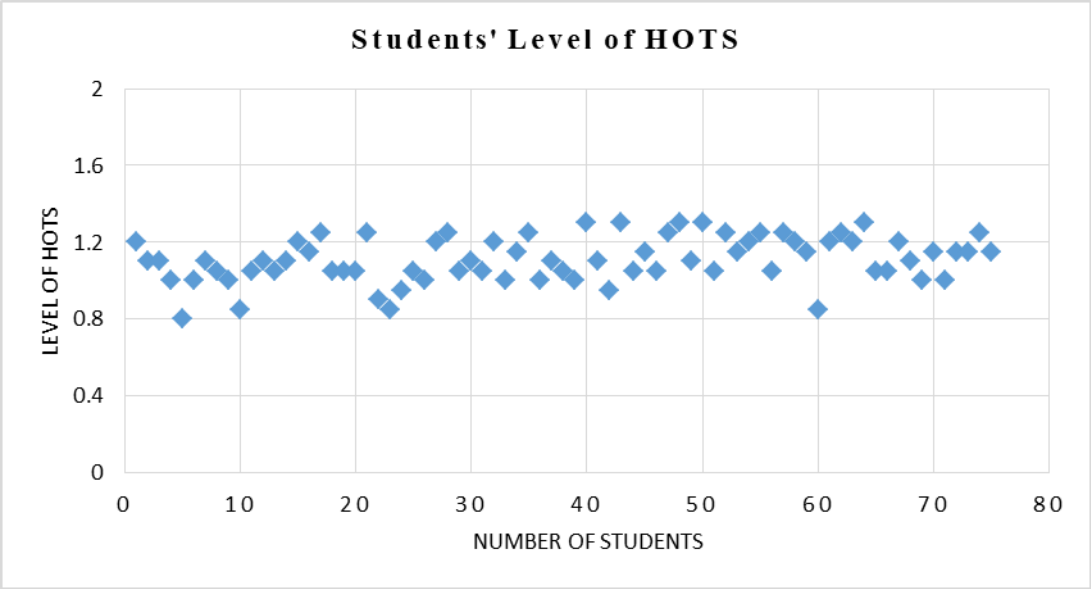

Fig .1. Grafic student's Level of HOTS

Table 8. Students' level of HOTS based on the Domain

Level of HOTS	Number		Algebra		Geometry		Data and Chance	
Low	23	30.67%	49	65.33%	42	56.00%	49	65.33%
Moderate	47	62.67%	24	32.00%	18	24.00%	21	28.00%
High	5	6.67%	2	2.67%	15	20.00%	5	6.67%

Table 8 showed that students feel that Algebra, geometry and Data and Change is still challenging. 65.33% students at "Low" level at Algebra, 56% students at "Low" level at Geometry, and 65.33% students. Number seems to be the least challenging content for students by having 30.67% "Low" level students. Surprisingly, on Geometry content, there are 20% students at "high" level. It means they are able to give reasons with geometry figures to solve problems and to use line, angle, shape, and space to solve problems and analyze data.

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