Profile of Superior High School Students' Higher Order Thinking Skills on Stoichiometry Topic

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A B S T R A C T

The world has entered the industrial revolution (RI) 4.0 which is supported by digital technology and automation in various fields. RI 4.0 resulted in changes in the social order, specifically the need for skills in this era. The top 3 skills needed in the 21st century are complex problem solving, critical thinking, and creativity. All of these skills can be classified into Higher Order Thinking Skills (HOTS). HOTS is a thinking skill that depends on the ability to analyze, create, and evaluate all aspects and problems. This research aims to develop valid problems to measure HOTS for students on stoichiometry topic and evaluate students' HOTS on stoichiometry topic. Research is a development research type formative research that consists of analyzing, designing, evaluating, and revising. All data are analyzed using a descriptive technique. A subject in this research is students of superior high school in Pekanbaru. The results of this research are: (1) three of valid HOTS problems on stoichiometry (2) value of students' HOTS on stoichiometry is 35.16 which put in a medium category.

1. Introduction

Human has entered a world that change rapidly in all sectors. The industrial sector has entered a new era in development and production which we call the Industrial Revolution (IR) 4.0 or Industry 4.0. Industry 4.0 will involve the technical integration of Cyber-Physical Systems (CPS) into manufacturing and logistics and the use of Internet of Things (IoT) and Service in industrial process (Kagermenn et al., 2013). IR 4.0 affects business, governance, people, and education (Hussin, 2018). Education is responsible for preparing the next

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generation to face challenges in the 21st century. The biggest challenge in the 21st century is to prepare our students to contribute to the world of work and civic life (Trilling & Fadel, 2009).

The 21st century is a digital and automation era that requires different skills than the previous era. The top 3 skills needed in the 21st century are complex problem solving, critical thinking, and creativity (World Economic Forum, 2016). Trilling and Fadel (2009) say that the first set of 21st-century skills focuses on critical thinking, problem-solving, communication, collaboration, creativity, and innovation. All of these skills can be classified into Higher Order Thinking Skills (Krathwohl et al., 2001). HOTS is a thinking skill that depends on the ability to analyze, create, and evaluate all aspects and problems. This requires someone to apply new information or prior knowledge and manipulate information to achieve possible answers in new situations. Heong et al. (2011) stated that HOTS are teachable and learnable for all students in the classroom.

The Indonesian government has tried to improve the quality of education by improving teacher competencies and developing the national curriculum (Sukasni et al., 2017). The 2013 Curriculum is a national curriculum that has been applied to answer the challenges of education in the digital era. The 2013 Curriculum is designed to strengthen the competencies of the learners such as knowledge, skills, and attitude as a unity (Rudy, 2015). The 2013 Curriculum focuses on the ability to observe, ask, reason, and communicate what they have acquired so that it is expected to increase HOTS students (Mardiana et al., 2017). Yennita et al., (2018) concluded that the use of HOTS worksheets could improve students' HOTS.

Some superior schools in Pekanbaru city have used the 2013 curriculum for several years. Chemistry is one of the subjects taught in high school. Hidayah and Zanaton (2018) have found that students' attitude towards chemistry (enjoyment of learning chemistry) was at a high level while chemophobia (chemistry learning anxiety among students was at a moderate level. One of the materials taught in high school chemistry subjects is stoichiometry. Stoichiometry is the fundamental topic for chemical calculations and is a prerequisite for several other materials such as solution chemistry, chemical equilibrium, kinetics, acid bases, colligative solutions, and others. Mastery of stoichiometric material is emphasized in mastering concepts and chemical calculations. The questions in stoichiometry are often associated with the problems of students' daily lives so students are required to have HOTS in order to learn them well.

Research on HOTS profiles has been carried out by various researchers. Chae et al. (2018) have done research about determinants of latent profiles in HOTS of Korean University Students. They found that the use of HOTS could be classified into four classes (lower-order thinking, a creative-argumentative, an analytical-caring, and HOTS class). Utami et al. (2017) have done research about critical thinking skills profile of high school students in learning chemistry. They found that high school students have adequate critical thinking skills in chemistry learning. Kusuma et al. (2017) have successfully developed an instrument for assessing HOTS in static fluid material based on the cognitive dimension process,

knowledge dimension, factual knowledge, conceptual procedure, and metacognitive. Saadah et al. (2019) have succeeded in developing a multiple choice valid and reliable HOTS test for class X high school material.

This research aims to develop valid problems to measure Higher Order Thinking Skills (HOTS) for students on stoichiometry topic and evaluate students' HOTS on stoichiometry topic.

2.   Methodology

This research was conducted at Pekanbaru Superior High School. The study was conducted from March to September 2018. The study population was all Pekanbaru superior high school students, while the study sample was 11th-grade students who were selected by purposive random sampling technique. Research is a development research type of formative research. This development research is a type of research aimed at developing questions to measure HOTS through several stages as in Figure 1 (Tessmer, 1993).
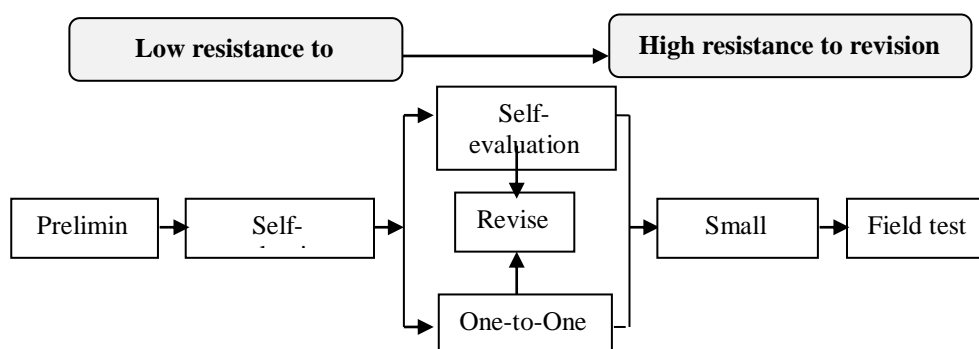

Figure 1. Flowchart of Formative Evaluation

Preliminary stage

At this stage is to determine the place and subject of the research and make other preparations, such as arranging the research schedule and procedures for collaboration with related parties.

Self-Evaluation stage

This stage is the first step of development research. Researchers, in this case, will analyze students, analysis of material, curriculum and literature, which are in accordance with the syllabus. The next step, researchers designed questions to measure high order thinking skills in the subject of stoichiometry. The design of this product as a prototype. Each prototype focuses on three characteristics, namely: content, construct and language. This is as shown in Table 1. These three characteristics are validated by experts and peers. This method is known as triangulation technique.

Prototyping (validation, evaluation, and revision)

At this stage, the product that was created will be evaluated. In this evaluation phase, the product will be tested. There are 3 groups of trials in this stage.

(a) *Expert Review and One-to-one*
   The design results in the first prototype developed on the basis of self-evaluation were given to experts (expert review) and one student (one-to-one) in parallel. From the results of the two made revision material.

(b) *Expert judgment*
   At this stage, the products that have been designed will be observed, assessed and evaluated by experts. These experts will examine the content, construct, and language of each prototype. The responses and suggestions from the validators about the designs that have been made, the validator's suggestions are written on the validation sheet-like material for revising and states that the questions to measure HOTS are valid.

(c) *One-to-one*
   Researchers use a student as a tester. The results of student comments will be used to revise the design questions that have been made.

Table 1.Criteria for development HOTS' questions

Criteria	Explanation
Content	• Test questions measure critical thinking skills in accordance with the • Basic competence • Indicator • Learning objectives
Construct	• The questions are in accordance with the theory that supports the criteria: • Develop the ability to analyze, evaluate, and create • Rich with concepts • In accordance with student level • Invite further concept development
Language	• In accordance with EYD • The problem is not complicated • The problem does not contain multiple ides • Clear questions and answers • using common language

Small group

The revision of the expert and the difficulties experienced by the students when testing the first prototype made the basis for the revision of the design of the first prototype called the second prototype. Then the results were tested on the small group. Five students will be asked to solve the questions that have been designed. Based on the results of the test results and student comments, the product was revised and corrected.

Field Test

The suggestions and the results of the trial on the second prototype were used as a consider for revising the design of the second prototype. The results of the revision were tested into the research subject in this case as a field test. Data were collected by a written test. A test was used to obtain data from HOTS students. The test consists of 3 questions in the form of descriptions essays which refers to indicators of HOTS ability. There are two questions with C4 and one question C5 according to level on Taxonomy Blooms.

Data analysis techniques

The scores obtained by students in working on questions are used as criteria for assessing students' HOTS. The maximum score for each question is 20, while the minimum score is 0. The variation in student scores depends on the corrector by considering several aspects, namely mastery of concepts, completeness of answers, and logical argument. Students are grouped into 3 groups based on HOTS values, which are low, medium, and high.

Grouping steps are carried out as follows: First, find the minimum value by multiplying many test questions with the lowest score of the scoring system for HOTS. The second step, finding the maximum value by multiplying many test questions with the highest scoring system for each HOTS. Third, determine the data range. The final step, divide the range the data becomes 3 parts so that the class interval is obtained. The low, medium and high-grade intervals reflect the low, medium, and, high-level students' HOTS alternatively as shown in Table 2.

Table 2. Grouping of students' HOTS

Score	HOTS category
$0 \leq \text{Score} \leq 25$	Low
$25 < \text{Score} \leq 40$	Medium
$40 < \text{Score} \leq 60$	High

3. Results and Discussion

Development of HOTS question in stoichiometry

The development of HOTS questions in stoichiometry topic results in three essays questions with valid criteria by expert judgment. Indicators of 3 HOTS questions that have been successfully developed are summarized in Table 3.

Table 3. Indicators of HOTS Questions

No	Sub Topic	HOTS Questions Indicator	Cog
1	Determine of elements percentage in a compound	Students are given data on fertilizers including molecular formulas, mass, and prices. Students are asked to determine the most economical type of fertilizer specifically for certain elements	C5

2	Determine of empirical formulas and molecular formulas	Students are given data about the percentage of elements in compounds and mass for 3 molecules in grams. Students can determine the empirical formula and molecular formula of the compound	C4
3	Determine of the percentage of hydrate compounds in the mixture	Students are given two types of hydrate compounds in a mixture with a certain mass. The mixture is heated and data on mass after heating is obtained. Students are asked to determine the percentage of hydrate compounds in the mixture	C4

Field Test

A total of 3 valid HOTS questions were tried out to 25 students. They are given 50 minutes to answer all the questions. Then, they are then grouped based on the total score into a low, medium, and high groups as shown in Table 4.

Table 4. Distribution of students' HOTS

Score	Frequency	Percentage	HOTS category
$0 \leq$ Score ≤ 25	4	16	Low
$25 <$ Score ≤ 40	14	56	Medium
$40 <$ Score ≤ 60	7	28	High
Total	25	100	
Average	-	35.16	Medium

Based on the data in Table 4, it can be seen that the number of students with low, medium and high HOTS is 4, 14, and 7 respectively. Average students' HOTS on equilibrium topic is 35.16 which put in a medium category.

Based on the data in table 4, we can see that the average HOTS of students is a medium category. This indicates that the implementation of the 2013 curriculum has been carried out quite well by the teacher in the class. Because to improve students' HOTS in science, the teaching of the 2013 curriculum requires teachers to use appropriate teaching methods to engage student's active participation in the learning process (Saido et al., 2015). HOTS problems on the stoichiometry topic are presented in Indonesian to students. HOTS problems were developed with reference to various literature, such as journals, books, and exam questions. It aims to measure and distinguish students' HOTS in their groups. The difference between students' answers based on HOTS order is well produced by number 2 problem is shown in Figure 2.

Students will be able to answer the problem of number 2 well if they are able to:
a) Mastering the concept of moles, the composition of elements in compounds, molecular formulas, empirical formulas, and the relationships between these concepts
b) Can determine the empirical formula of the percentage of the mass of elements in a compound
c) Can determine the relative molecular mass of the mass of a compound
d) Can determine molecular formula from empirical formula and relative molecular mass data

> *Tetrodotoxin is a toxic chemical found in fugu pufferfish, a popular but rare delicacy in Japan. This compound has an LD_{50} (the amount of substance that is lethal to 50% of a population sample) of 10 µg per kg of body mass. Tetrodotoxin is 41,379% carbon by mass, 13,166% nitrogen by mass, and 5,329% hydrogen by mass, with the remaining amount consisting of oxygen.*

Figure 2. A problem of HOTS

According to students' answer for HOTS problems on stoichiometry topic, students are grouped by 3 groups, namely student with High, Medium, and Low HOTS. The students' answer for number 2 HOTS problem which represents his group is presented below:

(a) **The student with a High HOTS**

Student's answer with a High HOTS is presented in Figure 3. This student successfully completes the test well. He mastering all concepts about moles, the composition of elements in compounds, molecular formulas, empirical formulas, and the relationships between these concepts. Then, he knows what the problem is and how to solve it. Table 4 shows that students with a High HOTS just 7 students. Most students have difficulty solving truly new problems in HOTS stoichiometry. We suggest that learning in the classroom is not good enough in improving students' creative thinking skills. Because creative thinking pedagogy should help the student more innovative ideas and imaginative insights to solve any problem in their world (Chinedu et al., 2015).
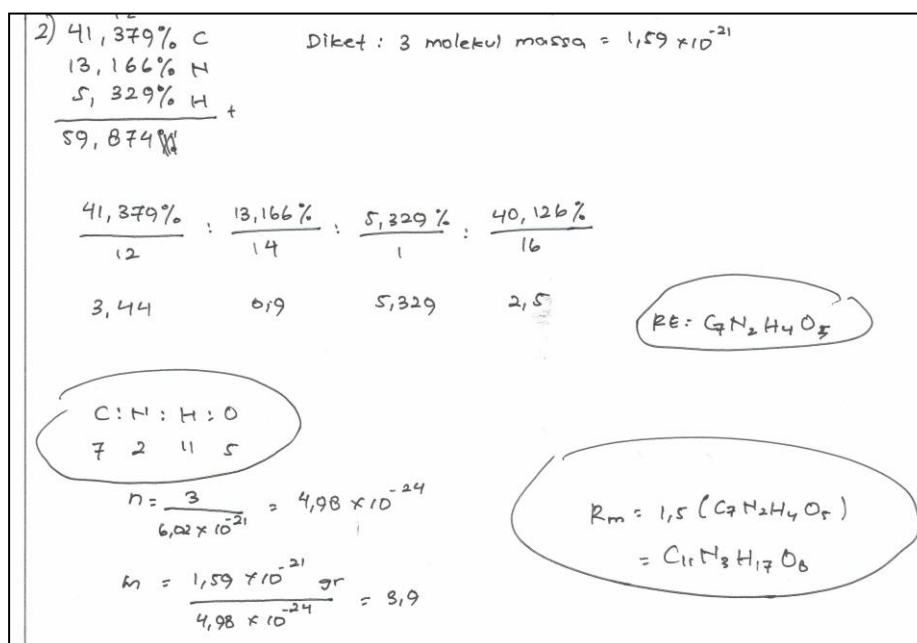

Figure 3. Answer of Student with a High HOTS

This student has a logical and systematic mindset seen from the answers given. He began to answer by calculating the percentage of all elements in the compound and comparing the mole values. Then, he determines the molecular formula of the relationship of the empirical formula and the relative molecular mass. The lack of student answers lies in the absence of an explanation of the results obtained. This can be caused by student' learning habits in class. It can be ignored in the assessment because the problem does not ask for an explanation of the results obtained.

(b) The student with a Medium HOTS

Student's answer with a Medium HOTS is presented in Figure 4. This student answers the question well enough. He mastering all concepts about moles, the composition of elements in compounds, molecular formulas, empirical formulas, and the relationships between these concepts. However, he could not properly apply the concept he had in the calculation.
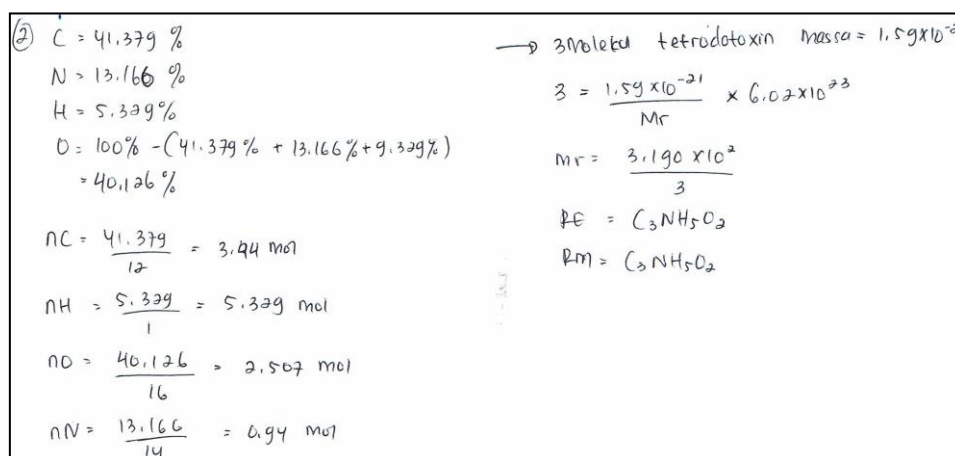

Figure 4. Answer of Student with a Medium HOTS

Based on the answers, he has known what the problem is and how to solve it, but he is less careful in determining the empirical formula and molecular formula of the compound. This student has a logical and systematic mindset, but less careful in answering the question.

(c) The student with a Low HOTS

Student's answer with a Low HOTS is presented in Figure 5. This student is not good at answering the questions given. Although he mastered all the concepts of moles, a composition of an element in compounds, molecular formulas, empirical formulas, and the relationships between these concepts, he could not apply the concept he had in the calculation. He knows about the problem given in the problem, but he doesn't know how to solve it. This student has a mindset that is less logical and less systematic, and not careful in answering questions.
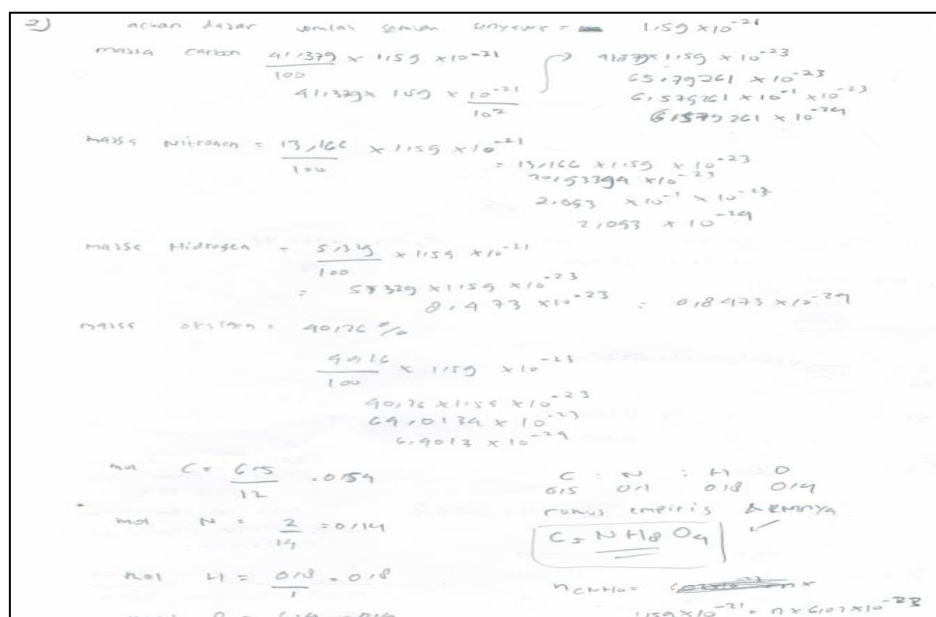
Figure 5. Answer of Student with a Low HOTS

4. Conclusion

Based on the analysis and interpretation of the data obtained from this research, it can be concluded that HOTS problems on the stoichiometry topic are successfully developed. The test consists of 3 essay questions to measure the students' HOTS on stoichiometry topic. Students' HOTS belongs to the medium category. Although most students demonstrate HOTS, only a small percentage of students demonstrate creative thinking skills.

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