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PROFILE OF CHEMICAL TEACHER CANDIDATES' HIGHER ORDER THINKING SKILLS (HOTS) ON IONIC EQUILIBRIUM IN SOLUTION TOPIC

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Abstract

This research aims to (1) develop valid questions to measure Higher Order Thinking Skills (HOTS) for chemical teacher candidates on ionic equilibrium in solution topic (2) evaluate chemical teacher candidates' HOTS on ionic equilibrium in solution topic. Research is a development research type formative research that consist of analyzing, designing, evaluating, and revising. All data are analyzed using descriptive technique. Subject in this research are chemical teacher candidates of University of Riau Chemical Education Study Program. The results of this research are: (1) four of valid HOTS open-ended questions on ionic equilibrium in solution topic. (2) value of chemical teacher candidates' HOTS on ionic equilibrium in solution topic is 33.18 which put in medium category.

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INTRODUCTION

Education is an important key in the development of any nation. Good education will create good human resources who are able to compete with other human beings in globalization era. Based on data released in 2016 by UNDP, the value of Human Development Index (HDI) for Indonesia is 0.689. This puts Indonesia in the 113th position of the 180 countries studied (UNDP, 2016). Single effort that can be done to significantly improve the HDI is through a good education system.

The Indonesian government's effort to improve education is by developing a curriculum that can train Higher Order Thinking Skills (HOTS). The curriculum is a 2013 Curriculum which was launched by the Ministry of National Education starting in 2013 as a form of the 2006 Curriculum development. The 2013 Curriculum focuses on the ability to observe, ask, reason, and communicate what students have gained (Mardiana and Sumiyatun, 2017). The implementation of the 2013 Curriculum is expected to produce innovative and creative Indonesian people through strengthening integrated attitudes, skills, and knowledge (Kemendikbud, 2013).

Reality is different than expected. Although the 2013 curriculum has been running for several years, there is no significant improvement in the ability of Indonesian students to HOTS. This is evidenced by the TIMSS research in the year 2011 and 2015 which measured the ability of students from various countries in the world in terms of conducting scientific procedures. This research revealed that Indonesian students were ranked 38 out of 42 countries (in 2011) and ranked 36 out of 49 countries (2015) (TIMMS, 2016)

This study also revealed that Indonesian students were weak in all aspects of content and cognitive, both for mathematics and science. They only master routine questions, simple computing, and measure knowledge of daily contextual facts. So, they need to strengthen HOTS, such as integrating information, drawing conclusions, and generalizing their knowledge to other things (TIMMS, 2016). In addition, Based on OECD data, Indonesian students can only perform on the first level to fourth level, while for a higher level, Indonesian students have difficulty completing it (OECD, 2016). These things prove that the ability of Indonesian students is still low.

The ineffectiveness of the 2013 Curriculum in increasing students' HOTS can be caused by a lack of teacher competency. Because teachers are know best about the practice of teaching and are responsible for introducing the curriculum in the classroom (Alsubaie, 2016). Professional competency of teacher has a significant contribution in improving learning performance in the classroom (Hakim, 2015). According to study by Chang *et al* (2013), Indonesian teachers had low overall competency compared with teachers in neighboring countries. In addition, Indonesian certified teachers have not been effective in improving student learning outcomes (Kusumawardhani, 2017).

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). In short, HOTS is thinking at a higher level than just memorizing facts.

The ionic equilibrium in solution is the subject of chemistry that really requires HOTS because of the wide scope of the topic. This topic covers the sub-topic about buffer solution, salt hydrolysis, solubility and solubility products, and solution colligative properties. To solve problems in this topic, students need a solution procedure that can be used in these different didactic situations and that can suit very different reasoning style (Cardellini, 2000). Furthermore, students are required to analyze, sort, and link the relationships between concepts on the topic. If all this have been well controlled by students, then it can be said that students already have HOTS.

The research to develop questions to measures HOTS and try out to students have been done by Lewy et al (2009) in SMP Xaverius Maria Palembang on Number Sequences and Series topic. Kusuma *et al* (2017) have done research about development of assessment instrumen for measure HOTS in physics study. Based on the the literature study that has been done, the authors are interested to conduct research entitled "Profile of Chemical Teacher Candidates' High Order Thinking Skills (HOTS) on Ionic Equilibrium Topic".

METHODS

This research was conducted in Chemical Education Study Program of University of Riau. The study population was all teacher candidates of the chemical education study program, while the study sample was the final semester students who were selected by purposive random sampling technique. Research is a development research type formative research (Tessmer, 1993). The purpose of this study is to produce and develop open-ended problems and to determine the profile of chemical teacher candidates HOTS on ionic equilbrium topic through several stages as in Figure 1.

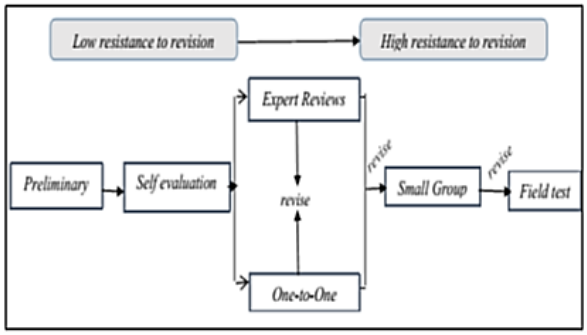

Figure 1. Flowchart of formative evaluation

Figure 1 shows that the research method consisting of several stages:

(1) Preliminary stage

Researchers determine the place and subject of the research and make other preparations.

(2) Self-evaluation

Researchers develop questions to measure HOTS in ionic equilibrium subject. The development result is called a prototype I. Prototype I focuses on three characteristics, namely: content, construct and language.

(3) Expert reviews and one-to-one stage

Prototype I is given to experts (expert review) and one student (one-to-one) in parallel. The responses and suggestions from the experts about the prototype I are written on the validation sheet. Researchers use a student as a tester. The prototype I was revised based on expert judgment and student comments. The revision result is called Protype II.

(4) Small group

The prototype II were tested on the small group. Five chemistry teacher candidates will be asked to solve the prototype II that have been developed. Prototype II was revised based on the tests that have been carried out. The revision result is called the final prototype.

(5) Field test

The final prototype were tested into the research subject in this case as a field test.

Data Analysis Techniques

The scores obtained by teacher candidates in solving the questions are used as a rationale for assessing teacher candidates' HOTS. A teacher candidate's response to an open-ended problems should be assigned a score according to how his/her understanding of ionic equilibrium in solution. The open-ended type of question is very useful for assessing whether the students have clearly grasped a certain concept. Scoring system are modified from SQA (2010) as shown in Table 1.

Table 1. Scoring system

Score	Criteria
16-20*	The maximum available score will be awarded to a student who has demonstrated a **good understanding.** Student shows a good comprehension of the chemistry of the situation and has provided a logically correct answer of the question posed
11-15*	The student has demonstrated **reasonable understanding.** Student makes some statement that is relevant to the situation, showing that the question is understood.
6-11*	The student has demonstrated a **limiting understanding.** Student has made some statement that is relevant to the situation, showing that at least a little of the chemistry within the question is understood.
0-5*	The student has demonstrated **no understanding**. There is no evidence that the student has recognized the area of principle. This score would also be given when the student merely restates the chemistry given in the question.

*score variation is determined by the accuracy, completeness, and clarity of the argument

Teacher candidates are grouped into 3 groups based on their scores, which are low, medium, and high HOTS. Grouping steps are carried out as follows: First, we look for the minimum value by multiplying many test questions with the lowest score of the scoring system. The second step, we look for the

maximum value by multiplying many test questions with the highest scoring system for each questions. Third, determine the data range. The final step, divide the range the data becomes 3 parts, so the class interval is obtained.

RESULTS AND DISCUSSION

The development of HOTS questions resulted in four open-ended problems with valid criteria by expert judgment. The indicators of 4 HOTS questions that have been successfully developed are summarized in Table 2.

Table 2. Indicators of HOTS Questions

HOTS Question Indicators	Cog
Student is given 2 ways to determine $[H^+]$ in a solution containing weak acids. The first way using Butler approach to solve the equilibrium equations of weak acid ionization. The second way using equilibrium equations to solve the questions. Students can determine the tolerance limit of the calculation results by using the Butler apprsoach and the acid-base equilibrium equation along with the reasons.	C5
Student is given the case of using medicinal ingredients, trichloroacetic acid (TCA). Students can determine the concentration of TCA which is unksnown in concentration by providing data about the decrease in the freezing point of the TCA solution and the TCA equilibrium constant value.	C4
Student is given about the formation of kidney stones (CaC_2O_4) and the factors that influence it, including the concentration of Ca^{2+}, $C_2O_4^{2-}$, and urine pH. The urine pH of normal and vegetarian people is different, so the risk of kidney stone formation between normal people and vegetarians is different. Students can explain which are more at risk have kidney stones whether normal or vegetarian.	C5
Student is given information about how to make an infused solution that has the same properties as human blood. It must have same pH and isotonic with blood. Student can makes infused solutions in the form of isotonic buffer solutions with blood.	C6

HOTS open-ended questions was developed regarding to various literature, such as journals, books, and exam questions. It aims to measure and distinguish HOTS teacher candidates in their groups. A total of 4 valid HOTS open-ended questions were tried out to 34 teacher candidates. They are given 60 minutes to answer all questions. The finding regarding students' achievement in solving HOTS questions are summarized in Table 3. Only 23.53% of teacher candidates achieved high level score and can be considered to be high HOTS category.

Table 3. Distribution of teacher candidates' HOTS

Score (X)	Percentage	HOTS category
$0 \leq X \leq 27$	47.06	Low
$27 < X \leq 54$	29.41	Medium
$54 < X \leq 80$	23.53	High
Average	33.18	Medium

The difference of understanding between chemical teacher candidates according to their response for HOTS questions is well presented by number 3 of HOTS question (Figure 2). Question number 3 asks chemical teacher candidates to explain the reason to form kidney stones from by the precipitation of calcium oxalate. To answer this question, chemical teacher candidates must have a good understanding about acid-base equilibrium, solubility and solubility product, salt hydrolysis and linkage between these concepts. Their answer might include information about ionization steps of oxalic acid, Le Chatelier principle and constant value of equilibrium, calculation of $[H^+]$ ion in solution and pH, and solubility of calcium oxalate.

Some kidney stones form by the precipitation of calcium oxalate (CaC_2O_4; Ksp 2.3 x 10^{-9}). The pH urine varies from 4.5 to 8.0. Normal people have a urine pH 6, while Vegetarians have a urine pH 7-8. If average $[Ca^{2+}]$ in urine is 2.1 x 10^{-3}, and concentration oxalic acid in urine is 3 x 10^{-13} M, are they (vegetarians) more or less likely to form kidney stones?
(Ksp CaC_2O_4 = 4 x 10^{-9}; K_{a1} $H_2C_2O_4$ = 5.6x10^{-2}; K_{a2} $H_2C_2O_4$ = 5.4 x 10^{-5})

Figure 2. HOTS Questions Number 3

Question number 3 is open-ended problem that there is no unique correct answer. The advantage of using open-ended questions is that encourage and reward creativity and analytical thinking among chemical teacher candidates

(Surif *et al*, 2014). The following are the steps in completing question number 3 :

1. Write down the two stages of the oxalic acid ionization reaction.
2. Calculate [$C_2O_4^{2-}$] based on the equilibrium constant value and the concentration of oxalic acid for each condition, pH = 6 for normal people and pH = 7 for vegetarians.
3. Calculate the Qsp value of CaC_2O_4 regarding to [$C_2O_4^{2-}$] and [Ca^{2+}] in each condition.
4. Comparing CaC_2O_4 Qsp and Ksp values
5. Propose arguments based on calculations that have been done.

Question number 3 can distinguish chemical teacher candidates' HOTS well, following is chemical teacher candidates' response to question number 3 regarding to their HOTS level.

Chemical teacher candidate with a High HOTS

Response of teacher candidate with a High HOTS to question number 3 is presented in Figure 3. This teacher candidate successfully completes the test perfectly. He mastering all concepts about ionic equilibrium and be able to linkage between the concepts. Then, he knows what the problem is and how to solve it. In addition, he can evaluate which is likely to form precipitation by paying attention to Qsp and Ksp calcium oxalic value.

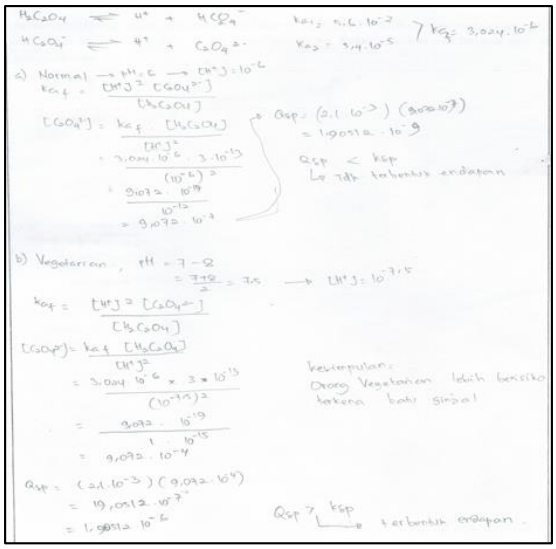

Figure 3. Response of High HOTS Teacher

Chemical teacher candidate with a Medium HOTS

Response of teacher candidate with a Medium HOTS is presented in Figure 4. He mastering concepts about calculation of solution pH, solubility and solubility products, and linkage about the concepts. He almost finished the test well, but he made a mistake in determining the [$C_2O_4^{2-}$] value. He should determine the value of [$C_2O_4^{2-}$] through the oxalic acid ionization equilibrium equation by considering the values of [$H_2C_2O_4$] and [H^+], but he only determines the value of [H^+] using the Butler equation without considering the values of [$H_2C_2O_4$] and [$C_2O_4^{2-}$].

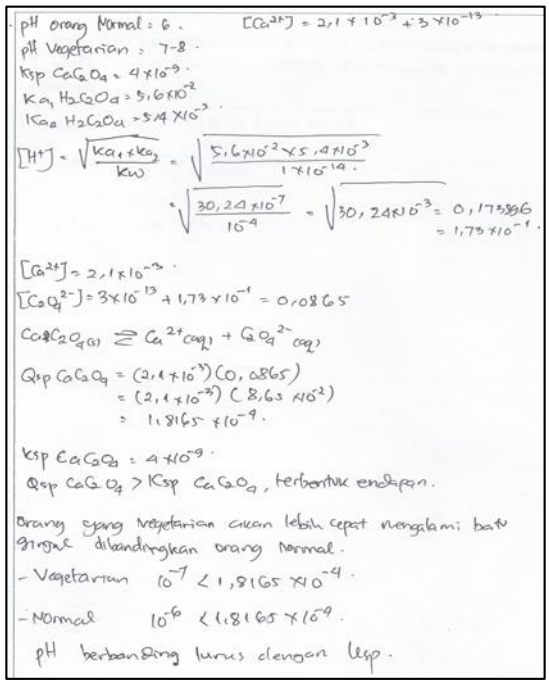

Figure 4. Response of Medium HOTS Teacher

Chemical teacher candidate with a Low HOTS

Response of teacher candidate with a Low HOTS is presented in Figure 5. This teacher candidate can not finished test well. He mastering concepts about calculation of solution pH and solubility and solubility products. But, he can not linkage between these concept. In addition, he confused what the problem is and how to solve the problem. This chemical teacher candidate can only solves problems about conceptual problems and routine computation.

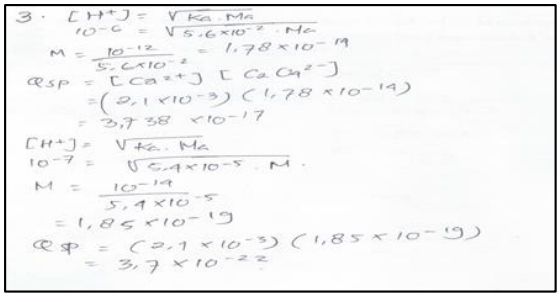

Figure 5. Response of Low HOTS Teacher

CONCLUSION

A total of 4 open-ended HOTS questions to measure teacher candidates' HOTS have been successfully developed with valid criteria and can measure the chemical teacher candidates' HOTS on ionic equilibrium in solution topic. Chemical teachers candidates' HOTS belong to the medium category with value 33.18.

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