Profile of Chemical Teacher Candidates' High Order Thinking Skills (HOTS) on Ionic EquilibriumTopic

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Abstract : This research aims to (1) develop valid problems to measure Higher Order Thinking Skills (HOTS) for chemical teacher candidates on ionic equilibrium topic (2) evaluate chemical teacher candidates' HOTS on ionic equilibrium 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 problems on ionic equilibrium topic. (2) value of chemical teacher candidates' HOTS on ionic equilibrium topic is 33.18 which put in medium category.

Keyword : Higher Order Thinking Skills (HOTS); chemical teacher candidates; ionic equilibrium.

1. 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 *United Nations Development Program*(UNDP), an institution that measures the Human Development Index (HDI), the value of 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 they 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 *TrendsinInternationalMathematicsandScience Studies* (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, revealed that Indonesian students were ranked 38 out of 42 countries (in 2011) and ranked 36 out of 49 countries (2015) (Pikiran Rakyat, 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, according to the Head of Puspendik, Nizam, said that Indonesian students are only good at working on memorized questions. However, in applying and reasoning is still low (Kompas, 2016).

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). According to study by Chang et al (2013), Indonesian teachers had low overall competency compared with teachers in neighboring countries. In fact, certified teachers in Indonesia have not been able to improve 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 matter about buffer solution, salt hydrolysis, solubility and solubility products, and solution colligative properties. In order for students to be able to solve problems in this topic, students must first know all the concepts in each material. 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 problems 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.

Based on the above description, the authors are interested to conduct research entitled "Profile of Chemical Teacher Candidates' High Order Thinking Skills (HOTS) on Ionic Equilibrium Topic"

2. Methodology

This research was conducted in Chemical Education Study Program of University of Riau. Research was conducted from April-September 2018. 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). This development research is a type of research aimed at producing questions to measure high-level thinking skills, through several stages as in Figure 1.

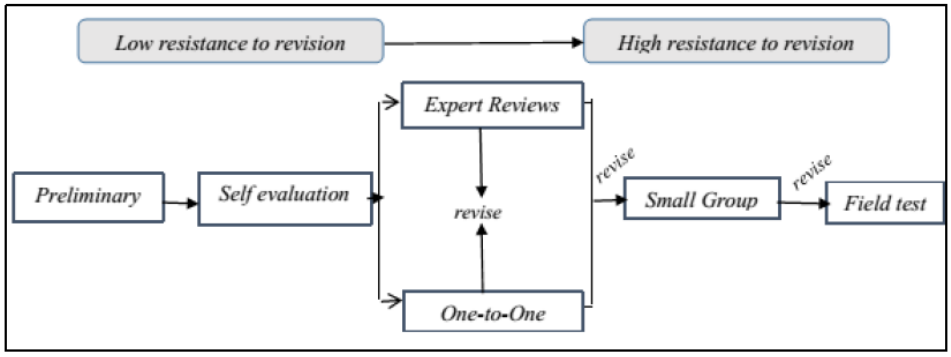


Figure 1. Flowchart of Formative Evaluation

(Tessmer, 1993)

2.1. *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

2.2. *Self Evaluation stage*

a. Analysis

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.

b. Design

At this stage, researchers designed questions to measure high order thinking skills in the subject of ion equilibrium. Design this product as a prototype. Each prototype focuses on three characteristics, namely: content, construct and language. This is as shown in Table 1.

Table 1.Criteria for development HOTS' questions

Content	• Test questions measure critical thinking skillsin accordance with the • Basic competence • Indicator • Learning objectives
Construct	• The questions is 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 ide • Clear questions and answers • sing common language

These three characteristics are validated by experts and peers. This method is known as triangulation technique

2.3. *Prototyping*(validation, evaluation, andrevision)

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 :

1) *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

2) *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 as material for revising and states that the questions to measure these high-level thinking skills are valid.

3) *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.

2.4. 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 (5 students of non-research subjects). Five chemistry teacher candidates 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.

2.5. Field Test

The suggestions and the results of the trial on the second prototype were used as a basis 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

2.6. Collecting data method

Data were collected by written test. Test was used to obtain data teacher candidates' HOTS. The test consists of 4 questions in the form of descriptions / essays which refers to indicators of HOTS ability. There are two questions with C5 , one C4, and one C6 level on Taxonomy Blooms.

In this study the HOTS indicators used are :

a) Analyze
   - Analyze information and divide or structure information into smaller parts for recognize patterns or relationship
   - Able to recognize and differentiate causes and factors the result of a scenario complicated.
   - dentify / formulate question

b) Evaluate
- Give an assessment of solutions, ideas and methodologies by using the suitable criteria or standard for ensure the value of effectiveness or the benefits.
- Make hypotheses, criticize and do testing
- Accept or reject something statement based on criteria which has been set

c) Create
- Generalize an idea or perspective on something
- Design a way to solve the problem
- Organize elements or the parts become new structures which has never been before

2.7. Data analysis techniques

a) Analysis of test results data

The scores obtained by teacher candidates in working on questions are used as a basis for assessing teacher candidates' HOTS.Scoring system are made as shown in Table 2.

Table 2. Scoring system

Score	Criteria
16-20*	3 descriptors are met
11-15*	2 descriptors are met
6-11*	1 descriptors are met
0-5*	0 descriptors are met

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

b) The grouping ofteacher candidates' HOTS

Teacher candidates 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 levelteacher candidates' HOTS alternatively as shown in Table 3.

Table 3. Categorization of teacher candidates's HOTS score

Score	HOTS category
$0 \leq$ Score ≤ 27	Low
$27 <$ Score ≤ 54	Medium
$54 <$ Score ≤ 80	High

3. Result and Discussion

3.1. Development of HOTS question

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

Table 4.Indicators of HOTS Questions

NO	TOPIC	HOTS QUESTIONS INDICATOR	Cog
1	Determine the pH of a weak acid or base solution	Two ways are given to determine $[H^+]$ in a solution containing weak acids, that is by using the Butler approach and how to solve the equilibrium equations of weak acid ionization. Students can determine the tolerance limit of the calculation results by using the Butler approach and the acid-base equilibrium equation along with the reasons.	C5
2	• Determine the value of the equilibrium constant of a weak acid or base • Determine solution colligative properties	Given the case of the use of medicinal ingredients trichloroacetic acid (TCA). Students can determine the concentration of TCA which is unknown in concentration by providing data about the decrease in the freezing point of the TCA solution and the TCA equilibrium constant value.	C4
3	• Determine the pH of salt hydrolysis • Determine the solubility and solubility product of salt • Determine whether or not salt is formed	Discourse is given about the formation of kidney stones (CaC_2O_4) and the factors that influence them, 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 of developing kidney stones whether normal or vegetarian.	C5
4	• Determine the solution colligative properties • Determine the pH of the buffer solution	The case is given in the form of how to make an infusion solution that has the same properties as human blood, which has the same pH as blood and isotonic with blood. Students can make infusion solutions in the form of isotonic buffer solutions with blood.	C6

3.2. Field Test

A total of 4 valid HOTS questions were tried out to 34 teacher candidates. They are given 80 minutes to answer all questions. Then, they are then grouped based on the total score into low, medium, and high groups as shown in Table 5

Table 5. Distribution of teacher candidates' HOTS

Score	Frequency	Percentage	HOTS category
$0 \leq$ Score ≤ 27	16	47.06	Low
$27 <$ Score ≤ 54	10	29.41	Medium
$54 <$ Score ≤ 80	8	23.53	High
Total	34	100	
Average	-	**33.18**	**Medium**

Based on the data in Table 5 it can be seen that the number of students with low, medium and high HOTS are 16, 10, and 8 respectively. Average teacher candidates' HOTS on equilibrium topic is 33.18 which put in medium category.

3.3. Discussion

All HOTS questions developed are presented in Indonesian for teacher candidates. HOTS problems was developed with reference to various literature, such as journals, books, and exam questions. It's aim to measure and distinguish HOTS teacher candidates in their groups. The difference between teacher candidates' answers based on HOTS level is well produced by number 3 problem (Figure 2).

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?

Figure 2. HOTS Problems : Number 3

Teacher candidates will be able to answer number 3 problem well if they be able to :

a) Mastering the concepts of acid-base equilibrium, solubility and solubility product, and salt hydrolysis.
b) Linking concepts about acid-base equilibrium, solubility and dissolution times, and salt hydrolysis.
c) Complete the calculation of ion concentration in the solution which is affected by the pH value
d) Evaluate the value of ion concentration in solution versus Ksp

The following shows how teacher candidates' answer for number 3 problem based on the HOTS level on ionic equilibrium:

a) Teacher candidate with a High HOTS

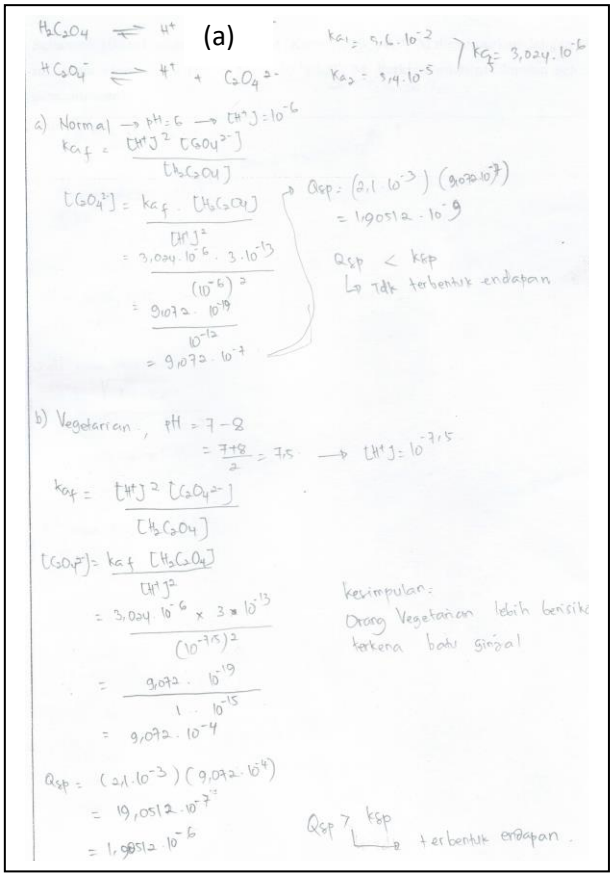
Answer of teacher candidate with a High HOTS is presented in Figure 3(a). This teacher candidatesuccessfully completes the test perfectly. He mastering all concepts about ionic equilibrium and be able to link between concepts. Then, he he knows what the problem is and how to solve it. In addition, he can evaluate which is likely to form deposits by paying attention to Qsp and Ksp value.

b) Teacher candidate with a Medium HOTS

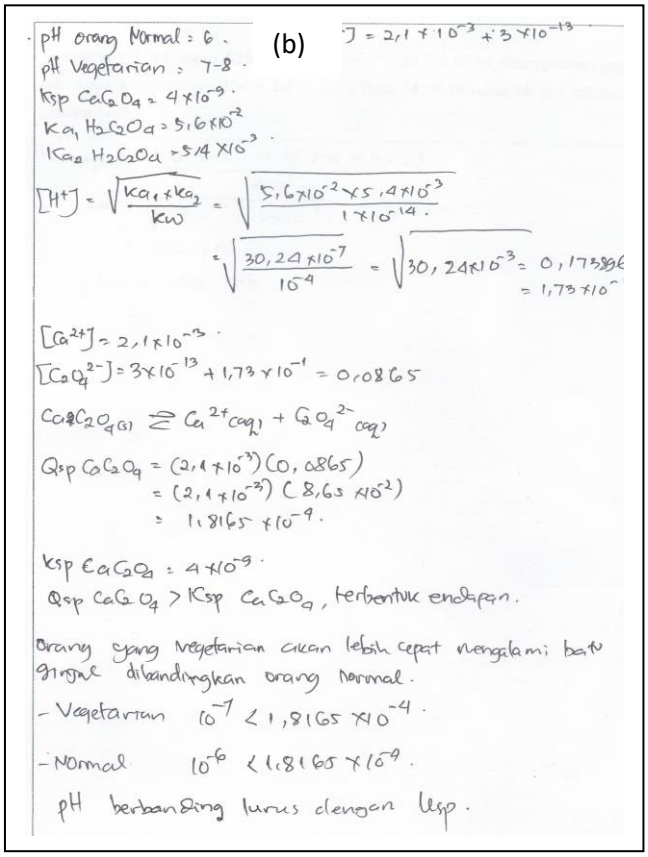
Answer of teacher candidate with a Medium HOTS is presented in Figure 3(b). This teacher candidate almost finished test well. He mastering concepts about

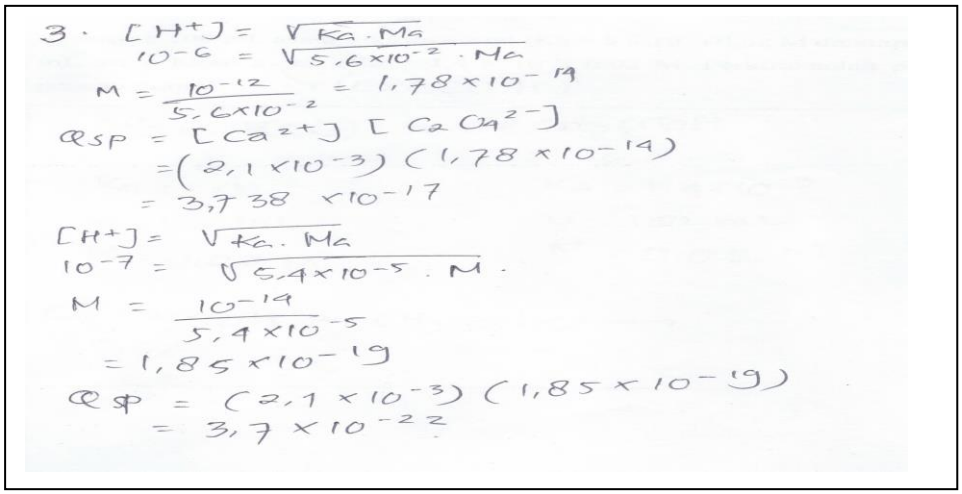
calculation of solution pH, solubility and solubility products, and link about the concepts. But, he confused what the problems is and where to start solve the problems.

(a)


Ka1 = 5,6.10^-2
Ka2 = 5,4.10^-5
Kf = 3,024.10^-6
a) Normal → pH = 6 → [H+] = 10^-6
Qsp = (2,1.10^-3)(9,072.10^-7)
= 1,90512.10^-9
Qsp < Ksp
↳ tdk terbentuk endapan
b) Vegetarian, pH = 7-8
= 7+8/2 = 7,5 → [H+] = 10^-7,5
Kesimpulan:
Orang Vegetarian lebih berisiko terkena batu ginjal
Qsp = (2,1.10^-3)(9,072.10^-4)
= 19,05512.10^-7
= 1,90512.10^-6
Qsp > Ksp
↳ terbentuk endapan.

(b)


pH orang Normal : 6.
pH Vegetarian : 7-8.
Ksp CaC2O4 = 4x10^-9.
Ka1 H2C2O4 = 5,6x10^-2
Ka2 H2C2O4 = 5,4x10^-5.
[H+] = √(Ka1 x Ka2 / Kw) = √(5,6x10^-2 x 5,4x10^-5 / 1x10^-14.)
= √(30,24x10^-7 / 10^-4) = √(30,24x10^-3) = 0,173886
= 1,73x10^-1
[Ca2+] = 2,1x10^-3.
[C2O4 2-] = 3x10^-13 + 1,73x10^-1 = 0,0865
CaC2O4(s) ⇌ Ca2+(aq) + C2O4 2-(aq)
Qsp CaC2O4 = (2,1x10^-3)(0,0865)
= (2,1x10^-3)(8,65x10^-2)
= 1,8165x10^-9.
Ksp CaC2O4 = 4x10^-9.
Qsp CaC2O4 < Ksp CaC2O4, terbentuk endapan.
Orang yang vegetarian akan lebih cepat mengalami batu ginjal dibandingkan orang normal.
- Vegetarian 10^-7 < 1,8165x10^-4.
- Normal 10^-6 < 1,8165x10^-9.
pH berbanding lurus dengan Ksp.



(c)

Figure 3.Teacher candidates' answer

(a) High HOTS; (b) Medium HOTS; (c) Low HOTS

(b)

c) Teacher candidate with a Low HOTS

Answer of teacher candidate with a Low HOTS is presented in Figure 3(c). This teacher candidatecan not finished test well .He mastering concepts about calculation of solution pH, solubility and solubility products. But, he can not link between the concept. In addition, he confused what the problems is and how to solve the problems.

4. Conclusion

A total of 4 essay questions to measureteacher candidates'HOTS have been successfully developed with valid criteria and can measure the chemical teacher candidates' HOTSon ionic equilibrium topic. Chemical teachers candidates' HOTS belong to the medium category with value 33.18.

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