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ENHANCING CRITICAL THINKING ABILITY OF PRESERVICE CHEMISTRY TEACHERS THROUGH MULTIPLE LEVELS OF REPRESENTATION

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ABSTRACT

Many students who think superficially, not the students who are able to think deeply and critically, graduated from school. Success of students in mathematical problem solving tends to be an indicator that the students have understood the concept of chemistry. Understanding of chemistry concepts should be demonstrated by the ability to transfer and connect among three levels of representation that consist of a macroscopic level, submicroscopic, and symbolic. This study aimed to enhance critical thinking skills of preservice chemistry teachers according to the indicators adapted from Ennis. Quantitative data obtained through test of critical thinking ability (CTA) which includes mastery of multiple levels of representation. The qualitative data obtained by interviewing several test subjects. Research design used pre-experimental design, one-group pretest-posttest design. Enhancement of concept mastery was measured by the score of pre-test and post-test through N-gain. Enhancements of CTA I indicator (elementary clarification), II (bassic support), and IV (advanced clarrification) at low level while the CTA III (inferring) and V (strategy and tactics) at medium level. There are indications that difficulties in connecting multipel level of representations because students do not interpret symbolic level which is mediator between the macroscopic level and submicroscopic.

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1. INTRODUCTION

Learning science is actually not only emphasis on understanding scientific concepts alone, but also on the ability of thinking. Liliasari (2011) argued that the study of science at the highest level is the "scientific thinking", which is essentially a high-level thinking (higher order thinking skills). Costa (1985) stated that there are four higher-order thinking, ie critical thinking, creative thinking, problem solving, and decision making. Liliasari (2009) further stated that based on some research, apparently understanding scientific concepts can be enhanced through the development of critical thinking skills of learners. In line with this, the educators felt that it was easier to teach science to students who have developed critical thinking skills.

Based on the depth of how to learn, science has 4 dimensions, namely: (1) science as a way of thinking, (2) science as a way of investigating, (3) science as knowledge, (4) science, and the interaction of science with technology and society (Chiapetta & Koballa, 2006). The different perspectives of science dimension can lead as to what the chosen way of learning science. Liliasari (2011) revealed that the science is still dominated by the dimension of knowledge whereas the dimensions of science as a way of thinking becomes the least practiced. Along with the ongoing changes of learning chemistry with emphasis on higher-order thinking skills, the paradigm of learning chemistry should also be changed. The change of paradigm of learning chemistry is the study of chemistry to be thinking through chemistry, which eventually became thought chemistry.

Santrock (2007, 2008) explained Many students who think superficially, not the students who are able to think deeply and critically, graduated from school. The success of learners in

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mathematical problem solving tends to be the standard that learners have understood the concept of chemistry. Learners also learn more about mathematical problem solving without make sense of what is intended. Students understanding of the chemical concepts should be demonstrated by the ability to transfer and connect among three levels of chemical representation consisting of a macroscopic, submicroskopic, and symbolic level which are essential characteristics in chemistry (Johnston, 2000a, 200b; Treagust & Chandrasegaran, 2009; Talanquer, 2011; Farida, 2012). In addition, the relationship among three levels should be explicitly taught (Treagust & Chandrasegaran, 2009).

One of the concepts that require the ability in multiple levels of representation is equilibrium in solution. This concept basically is closely related to the concept of acid-base solution. Contextually, concepts in this material plays an important role in many biological and environmental processes, for example: the process of controlling pH of human blood in order to keep the pH value (7.4) which involves equilibrium conjugate acid-base pair HCO3-and CO32-, water pH control in order to keep plants and aquatic life, the process of kidney stone formation and others (Chang, 2005; Mc Murry & Fay, 2006). Various research findings have expressed learners' difficulty on the concepts related to acids and bases (Orna, 1994; Drechsler & Schmidt, 2005; Çetingül & Geban, 2005; Sheppard, 2006; Halstead, 2009; Chaiyapha et al , 2011.; Rahayu, 2011; Metin, 2011; Muchtar & Harizal, 2012) as well as the concept of pH (Watters & Watters, 2006). In addition, the materials still associated with the chemical equilibrium in solution – acid and base chemical solution (Calik et al., 2005; Morgil et al., 2009) and the solubility and solubility product (Krause, S. & Tasooji, A., 2007) – are still often have misconceptions.

Based on the opinion that the effectiveness of chemistry learning in school is influenced also by the ability of teachers to understand and teach concepts to students, it is deemed relevant to improve the competence of preservice teachers to master chemistry concepts. Mastery of the concept can be improved along with the development of critical thinking skills of preservice teachers. Therefore, ehancement in critical thinking skills of preservice teachers must be very necessary.

Ennis (1985) stated that critical thinking is a mental activity that is both reflective and based on reasoning that is focused to determine what to believe and do. Reflective means considering actively, diligently and carefully to all alternatives before making a decision. This research aimed to improve students' critical thinking ability of preservice chemistry teacher in accordance with indicators adapted from Ennis (1985). Learning emphasizes mastery of multiple levels of representation.

2. RESEARCH METHOD

The design of experiment used a pre-experimental, One-Group Pretest-Posttest Design. Quantitative data were collected through test of critical thinking (TCT). TCT is a type of criterion-referenced test, tests used to measure students' critical thingking ability by certain criteria predefined by the evaluator without comparing with the other students' mastery or ability (Sukardi, 2009). TCT contained critical thinking ability indicators of Ennis (1985). TCT is an essay test containing the concepts of acid-base theory, buffers, hydrolysis concept, as well as the solubility and solubility product (Ksp). The qualitative data were collected through interviews with some of the test subjects as well as self-assessment of students. Test subjects were 38 students of chemical education at LPTK (an Institute for Preservice Teachers) in Semarang City, Central Java. Nevertheless, not all students can attend activities of pre test and post test, and fill out a self-assessment questionnaire. This was because learners have different activities. Furthermore, % N-g of concept mastery was analyzed to determine the level of improvement that occurred. This test was used to analyze the criteria for the achievement before and after learning (adapted from Hake, 1998). The criteria of achievement level of <g> that is 0,00 £ ‹g› < 0,30 = low; 0,30 £ ‹g› < 0,70 = médium; 0,70 £ ‹g› < 1,00 = high. Normality of data was tested with the Kolmogorov-Smirnov test using SPSS (Statistical Package for Social Science). If the results of the test data are normally distributed, the significance of differences in the results of scores before and after learning through Paired Samples t-test. If the data are not normally distributed, the test used Wilcoxon Signed Ranks Test (Cohen et al, 2007). Furthermore, to know the difference between the critical thinking skills of learners group, Kruskall Wallis test was used (Cohen et al, 2007).

3. RESULT AND ANALYSIS

Thinking activity is an activity that involves the manipulation and transformation of information in memory in order to form concepts, reason, critical thinking, and problem solving (Santrock, 2007). Critical thinking is the ability to analyze the patterns of thinking led to an argument

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and insight to each of meanings and interpretations. This thought pattern also serves to understand the underlying assumptions and biases of each position. Critical thinking can give a presentation model of a reliable, concise, and convincing (Ennis, 1985). Connection therewith, Sirhan (2007) stated that learning chemistry requires intellectual and critical thinking because the content is full of a lot of abstract concepts. Thus, the expected critical thinking ability are critical thinking ability related to mastery of chemistry concepts and content.

Adopting from the National Research Council in Santrock (2007), said that the students would actually master concepts if they are able to:

1. Detects the characteristics and patterns of meaningful information;
2. Gather more knowledge and organize it in a way that shows an understanding of the subject matter;
3. Take Back the important aspects of knowledge from memory with little effort.

By reviewing the definition of the ability to master the concept expressed by the NRC, it is known that the mastery of the concept is closely related to critical thinking ability. This is because the indicators of critical thinking is required to qualify mastery of concepts. expressed by the NRC.

The test of critical thinking ability is a lead in the mastery of the concept. The critical thinking skills that are reviewed in this study were: (1) elementary clarification, (2) basic support, (3) inferring, (4) advanced clarification; (5) strategies and tactics. To determine the condition of critical thinking ability before and after learning can be seen in Table 1.

Table 1. Description of Students' Critical Thinking Ability

Groups of Indicator	Ideal Score	Mean of Students' Score (N=31)	
		Pre-test	Post-test
CTA I	60	20,5	31,1
CTA II	60	19,6	30,2
CTA III	35	8,2	17,4
CTA IV	45	14,5	22,9
CTA V	50	9,2	23,5

Note:

N = Number of Students who take pre-test and post-test
CTA I = *Elementary Clarifiation*
CTA II = *Basic Support*
CTA III = *Inferring*
CTA IV = *Advanced Clarification*
CTA V = *Strategies and Tactic*

Results from the data in Table 1. then tested for the value of the gain and significant differences. The results obtained are presented in Table 2.

Table 2. Recapitulation of the analysis of Critical Thingking Ability

Group of Indicator	<g>	Differences Significance Tests	*Rank****		
			Negative	*Positive*	*Ties*
CTA I*	**0,27 (Low)**	Significant different	5	25	1
CTA II**	**0,26 (Low)**	Significant different	3	27	1
CTA III**	0,34 (Medium)	Significant different	0	31	0
CTA IV**	**0,27 (Low)**	Significant different	2	28	1
CTA V**	0,35 (Medium)	Significant different	1	30	0

Note:

* = Test used *Paired Samples t-test*
** = Test used *Wilcoxon Signed Ranks Test*
*** = Number of students who have a change scores and indicated by *Wilcoxon Signed Ranks Test*

It can be seen that the ability to infer and strategies & tactics are more developed than the other abilities. Operationally, the ability to conclude in question is the ability of learners to determine the appropriate conclusion and give reasons when presented a statement, information / data, and some possible conclusions. Furthermore, indicators of group strategy and tactics are the ability to judge.

Operationally, this ability is related to the ability to determine the positive and negative solutions, or most appropriate solution to solve the problem presented, and can give the reason.

The initial conditions of the misconceptions of the students have dominated the inability of the indicators CTA I, II, & IV. Thus, the low gain condition on CTA I, II, and IV can be understood. This is because it is basically very difficult to change misconceptions (Sanger & Greenbowe, 1997; Calik, 2005). Nevertheless, it is an increase in CTA I, II, & IV post-learning. This shows that the condition of the misconceptions that appear individually reduced (see Rank in Table 2.).

The low condition of gain on CTA I, II, and IV can be traced from the learners' answer. CTA I related to indicators focusing questions and analyzing arguments. The ability to focus the question related to the ability to identify the criteria for considering the correct answer. Thus, when presented an issue / problem, drawing models, or experiments and the results, the students have not been able to identify the criteria to consider the correct answer, and have not been able to give a good example. On the question "Give an example of a Lewis acid instead of Bronsted-Lowry acid? (Tips: in order to be seen clearly, show the reaction via the transfer of an electron pair) ", the students have not been able to identify the criteria of a lewis acid not included Bronsted Lowry acid. The majority of students' answers is the reaction between NH_3 and H_2O to form NH^{4+} and OH^-. In this condition, many students are forgetting the meaning of the writing phase of the substance and meaning of the reaction arrows. Thus, it can be seen that the majority of students have not been able to identify the criteria to write the correct equation, and have not been able to give a good example related to lewis acid that is not including the Bronsted-Lowry acid through reaction equation. This condition is due to the barrier as discussed previously.

The ability of learners to provide arguments related to the ability to identify and deal with imprecision, as well as identify sentences of question. One of TCT problem that showed is the acid-base titration curve. Students were asked to pay attention to the image of base titration curve between strong and weak acids and to correct (true / false) statements, as well as to provide a logical reason. Thus, when presented a description of a situation or argument, students have not been able to: (1) conclude arguments appropriately, (2) give reasons to support the arguments, (3) give reasons that not support the arguments. The majority of students have not been able to identify and deal with inappropriateness of the statements given. An example is the statement "At point B (Figure 1.) Solution is acidic because of hydrolysis". The majority of the students answered that it was true. Students may not realize inappropriateness that under these conditions, the concept of what happens is not hydrolysis but is buffer solution.

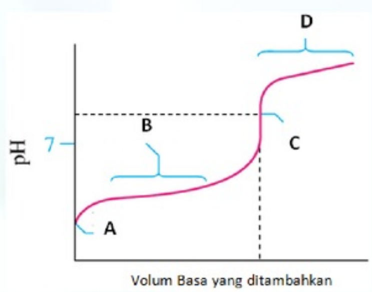

Figure 1. Titration curves between Weak Acid and Strong Bases

Besides CTA I, group indicator of CTA II also had low gain. CTA II was related to the ability of learners to give reasons and involves a bit of guesswork. For example, one of the TCT items presented "Graph of Relationship between Acid Molarity and Percent Ionization (Figure 2)," students were asked to give information about the tendency of a strong acid and a weak acid when dilution. The majority of students have not been able to involve a bit of conjecture to see the condition of the graph. Students have not been able to determine which parts of the graph which can be considered to review the conditions of the dilution. Students can not provide interpretation of graphs which if carried to infinite dilution, percent ionization of a weak acid near perfect (100%).

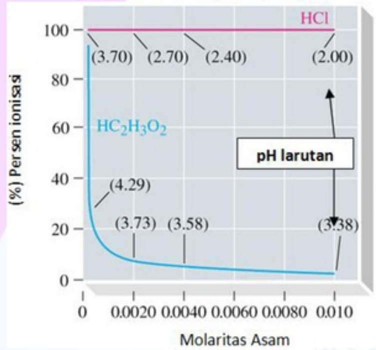

Figure 2. Graph of Relationship between Molarity and Percent Ionization Acid

CTA IV also increased on the low level. CTA IV had two indicators, namely to define and to describe the concept. The sub-indicators used in this study was the ability to act by providing further explanation, as well as provide an explanation not just a statement. Students were asked to explain "why it can be said that all Bronsted-Lowry acid is a Lewis acid, but not vice versa". The majority of students have not been able to give a proper explanation. The majority of students do not realize that the "Bronsted-Lowry acid theory can not be explained on a system that is not protonated, while the Lewis theory can explain on a system that does not protonated". Some examples of misconceptions that emerged was the notion that " Lewis acid just happens electron transfer, while the Bronsted-Lowry also occurs proton transfer ", as well as the assumption that the Bronsted-Lowry acid only use water as solvent ("Lewis acid is a refinement of the Bronsted-Lowry acid, only Lewis acids can use solvents other than water ").

Looking at the condition of the misconceptions that arise post-learning, it is certainly closely related to students' critical thinking ability. Critical thinking abilities among students categorized as mastery of the concept of MC (Mastering Concept), MMC (Mostly Mastering Concepts), MSFC (Mastering Small Fraction Concepts), and NMC (No Mastering Concepts) course different. It can be shown from the results of the Kruskall Wallis test in Table 3.

Table 3. Analysis of Critical Thinking Skills in Each Group of Concept Mastery

Group of Concept Mastery	N*	*Mean Rank*				
		KBKr 1	KBKr 2	KBKr 3	KBKr 4	KBKr 5
NMC (No Mastering Concepts)	5	6,30	5,60	4,60	4,60	3,40
MSFC (Mastering Small Fraction Concepts),	20	15,35	15,85	16,33	15,38	17,60
MMC (Mostly Mastering Concepts)	8	28,19	27,50	26,88	28,94	24,00
MC (Mastering Concept)	5	35,40	35,20	35,30	35,80	36,00
Total	38					

Note: * = Number of Students who take post-test.

Based on the results of Kruskall Wallis test, the value of Asymp Sig. on each of the indicators from CTA at (0,000). The value (0.000) <0.05 and indicate that there are significant differences of critical thinking ability among each group mastery of concepts (NMC, MSFC, MMC, and MC). By looking at the value of Mean Rank, it is known that MK students have the highest critical thinking ability, and followed by MSBK, MSKK, and TMK. It can also be known based on student interviews. For example, the results of the group interviews between "S1" (MC group), "S2" and "S3" (Group MMC). The following are excerpts of the discussion of the existence of Ka in strong acid.

(I) : Asam kuat itu punya Ka atau tidak? (does a strong acid have a Ka value?)
(S1), (S2), (S3): punya (Yes, it does)
(S1) : tapi nilainya kan gede. (but the value is big)
(I) : kok gede kenapa? (Why)

(S1) : karena kuat sih. (Because it is strong)
(S2) : eh...Ka itu apa sih?. (eh, what is Ka?)
(S1) : Konstanta. (A constant)
(I) : Tetapan ionisasi asam. (Acid ionization constants).
(I) : kok bisa tau gede..trus kenapa nilai Ka asam lemah itu kecil? (Why is the value of Ka of weak acid small?)
(S3) : karena ya itu. (because ...)
(S1) : tetapan ionisasi itu gimana nduk (S3). (what is the ionization constant, S3?)
(S3) : ya tetep terionisasi (still ionized)
(S1) : kenapa gede? ga pernah kepikiran. (why it is big...i don't think about it)
(I) : sekarang coba tulis HCl!. HCl kan asam kuat, yang lemah apa? (Let's write HCl!. HCl is a strong acid, give the example of weak acid!)
(S1) : o...CH3COOH
(I) : tulis dan direaksikan dengan H2O. (Write and react with H2O).
(S3) : Mari berimajinasi. (Let's imagine!)
(S1) : Mari berimajinasi..hehehehe
....
(I) : kamu tau Ka asam kuat gede dari mana? (Why do you know that Ka value of strong acid is big?)
(S1) : dari buku. (I know from the book)
(I) : lha kenapa kok gede?. Hanya sekedar tahu dan tidak bisa menjelaskan?. (Why the value is big?. Just know and you can not explain it, right?)
(S1) : mungkin karena H+-nya banyak atau apa? (sambil menulis persamaan reaksi). (Strong acid has many H+, i think..(S1 write the chemical equation of rection)).
(I) : Arah reaksinya jangan lupa..Nanti bisa dilihat dari simbol persamaan reaksinya. (Don't forget with the direction of reaction.. You can find the answer from the reaction equation).

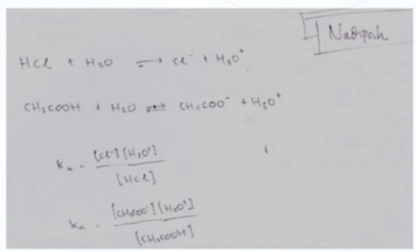

Figure 3. The Reaction Equation and The Ka Formulas Written by "s1"

(I) : Sekarang coba di logika sendiri...kenapa Ka asam kuat kok besar, Ka asam lemah kok kecil? (Let's try using logic...why Ka of strong acid has big value and Ka of weak acid has small value).
(S1) : Ow....
(I) : Gimana nadipah..udah tau kan? (Hi Nadipah...did you got it?)
(S1) : iya mas sudah. (Yes, i got it)
(I) : Arah panah menentukan kan? (The direction of arrow is very important, right?)
(S1) : he em. (Yes)
....

In this condition, S2 and S3 have not finished writing the reaction equation of HCl in water and CH3COOH in water.

(S3) : Jelasin... (S1, Let's explain us).
(I) : lho kamu belum (Did you not understand?)
(S2) (S3): belum (I didn't understand).
(S1) : Ka...Kesetimbangan biasa lah. (Ka is equilibrium)
(I) : Kamu belum paham kenapa Ka asam kuat besar dan asam lemah kecil? (Did you not understand that Ka of string acid is big and Ka of weak acid is small?)
(S2) : belum (i didn't understand)
(S3) : he em udah...tapi kenapanya yang masih kenapa. (Yes, i understand, but i don't know why).
(S3) : gimana nad? (why nad(S1)?)
(S1) : Ya itu sih...dari tanda panah...ini (HCl) kan terionisasi sempurna otomatis arah panahnya ke sana (ke kanan). Ke sini (ke kiri-arah reaktan- HCl+H2O) kan sedikit. Jadi kan gedean ini (konsentrasi produk- Cl- + H3O+)...Kalau dibagi dengan ini (konsentrasi reaktan) kan tambah gede...(nilai K pada asam kuat). Lha yang ini (asam lemah CH3COOH), ini paling

banyak ke sini (ke arah reaktan- CH3COOH + H2O). Jadi kan lebih gedean ini (konsentrasi reaktan) sehingga Ka- nya kecil (pada asam lemah).
(From the direction of arrow. HCl will be ionized totally so the direction to the right (product). Thus, the result in product is big. So, the concentration product, Cl- + H3O+ divided by concentration reactant, HCl+H2O is big value. The value of Ka is big. CH3COOH will be ionized partially so the direction of arrow to the left (reactant). Thus, the result in product is small. So, the concentration product, CH3COO- + H3O+ divided by concentration reactant, CH3COOH +H2O is smaall value. The value of Ka is small).

Based on the description of the results, learners will have mastered the concept of superior memory. Their way to enhance their superior memory is by using merger (chunking), the grouping of the pieces of information into one unit of the order of higher-level information, which can easily be remembered as one entity (Santrock, 2007). In line with this, Liliasari (2009) was also stated that teachers find it easier to teach science to students who have developed critical thinking ability. By looking at the condition of the discussion, it can be seen that the "N3" (MC group) have critical thinking ability more than the other two. The same thing was also seen in other sessions of group interviews.

In the interview session, "N3" has been able to identify the criteria for determining the answer "why the Ka of a strong acid has a great value?". Based on the description, it is known also that the ability of the symbolic level of "S1" was also better than the other two. This also happens on other interview sessions. The condition of the symbolic level MC groups influenced the direction of answer. MC groups interpret chemical symbols in depth than any other group of students. With interpret chemical symbols, the students are better able to criticize a given problem. By understanding the concept of symbolic appropriate, students will be able to connect the macroscopic conditions and submicroskopic. Symbolic level is the mediator between the macroscopic level and submicroscopic (Taber, 2009).

After learning activities charged multiple level representation, students have more knowledge about the levels of chemical representation and ultimately was also in tandem with changes in the ability of critical thinking. It is evident from the significant differences in each of the indicators, especially indicators of CTA III and V are at the level of gain "medium".

4. CONCLUSIONS

Enhancements of CTA I indicator (elementary clarification), II (bassic support), and IV (advanced clarrification) at low level while the CTA III (inferring) and V (strategy and tactics) at medium level. There are indications that difficulties in connecting multipel level of representations because students do not interpret symbolic level which is mediator between the macroscopic level and submicroscopic. Thus, educators are expected not only to make the completion of mathematical concepts to measure student mastery of chemistry concepts, but also to emphasize the interrelationship among macroscopic, microscopic, and symbolic level.

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