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PHASING CRITICAL THINKING ABILITY OF CHEMISTRY EDUCATION PROGRAM STUDENTS OF SEMARANG STATE UNIVERSITY IN SOLVING CHEMISTRY PROBLEM

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ABSTRACT

This study is a qualitative study. It aims to describe the level of critical thinking ability of students in solving chemistry problems, and describe the phases of critical thinking of students for each level of critical thinking skills. The data collection procedure consists of validation, problem solving test and task-based interview. The subject of the study were students of second semester in academic year 2014/2015. The data research is is the form of students' critical thinking level in solving chemistry problems. Based on the data analysis, the result obtained shows that the level of critical thinking ability of Chemistry Education program students from from Semarang State University in solving chemical problems consist of critical thinking ability level 3(critical), critical thinking ability level 2 (critical enough), critical thinking ability level 1 (less critical), and critical thinking ability 0 (Not critical). The result of the phasing students' critical thinking ability can be used as a guideline for assessment of critical thinking ability in learning chemistry. It also can be as a consideration for designing a model or learning strategies to improve critical thinking

Key Word: critical thinking level phasing, critical thinking ability, chemistry problem

INTRODUCTION

In the learning process, critical thinking is the highest level of thinking which related and able to be used in various situations including language use, conclusion, result calculation, decision making and problem solving (Paul and Nosich, 2004); it is obtained from observation, experience of common sense, or communication, and acts in decision making to solve problem. This statement is in line with Crawford's and Brown's (2002) that higher order thinking is the combination of critical and creative thinking as well as basic thinking. According to Mujis and Reynolds (2010), the ability of critical thinking is a part of higher order thinking, which is the process of heuristic thinking formed and developed through problems solving or challenges that involving the formal thinking. Siegel (1990) also emphasizes the strong relationship between critical thinking and rationality. *The Secretary's Commission on Achieving Necessary Skills* in 1990 states that the competence of critical thinking, decision making, problem solving, and reasoning as important matter in work achievement. Therefore, students from Chemistry education program of the Faculty of Mathematics and Natural Sciences (FMIPA) (Semarang State University) Unnes are expected as future educators to be having vision such as the ability of critical thinking, problem solving, decision making and creative thinking.

According to Widiyowati (2014), students' ability of critical thinking is paramount for students and needed to be built so that it becomes characteristics or personality of the students. The ability of good critical thinking can also shape their rational attitude and behavior as well as students they teach in solving the problem in Chemistry and students' self evaluations. Moreover, the ability of critical thinking can bring students to compete in this era which full of challenges (Widiyowati, 2015). Some experts in *The Californian Thinking* conclude that there are six core of critical thinking, which are interpretation, analysis, evaluation, conclusion, explanation and self-management ((Lambertus, 2009).

The learners' critical thinking ability can be trained through the provision of a problem in the form of various questions. To assess the level of critical thinking ability of students, researchers used five (5) indicators of critical thinking Ennis (1996), namely (1) is able to formulate the problem issues; (2) to reveal the facts needed to solve a problem; (3) is capable of selecting a logical argument, relevant, and accurate; (4) is able to detect bias based on different viewpoints; and (5) is able

to determine the result of a statement taken as a decision. Whereas the assessment standards adapted from Critical Thinking Model by Elder & Paul (2008) includes the clarity, accuracy, precision, relevance, logic, depth and vastness.

To assess whether a person belongs to a good or less critical thinker, can be seen from the abilities which are (interpretation), (analysis), (evaluation) and (inference), (explanation), and self-regulation (Facione, 2009). An ideal critical thinker has a great curiosity, actualized, his trustworthy reason, open-minded, flexible, balanced in evaluating, honest in facing personal prejudice, being careful in making decisions, willing to reconsider, being transparent on the issue, being smart in looking for relevant information, having reasons in selecting the criteria, being focus in the investigation, and being persistent in discovering the findings. Students can meet the aspect of interpretation if they are able to classify problems received so as to have a clear and meaningful sense. In the aspect analysis, students are able to test ideas and to identify some reasons and statements. In the aspect of inference, students can make a conclusion in problem solving. In the aspect of evaluation, students are able to assess the statement or opinion received by either oneself or others. In the aspect of explanation, students explain the statement or opinions that have ever been expressed before and make a strong opinion about it. In the aspect of self-regulation, students can organize themselves in facing the problem solving. Anyone who is able to perform these six cognitive abilities means that his critical thinking ability is far above anyone who is only able to perform the interpretation, analysis and evaluation only. Thus, it can be said that there is a hierarchy of critical thinking ability of a person. The level of critical thinking ability of each person is different and this difference can be seen as a continuum that starts from the lowest to the highest degree. If an individual is taken at random, then the individual can be placed on a certain level continuum of critical thinking.

In order to assess students' critical thinking abilities in problem solving activities, it requires a standard or criterion level of critical thinking. These criteria can be used as a guideline to determine the quality of students' ability to think critically and the development during the learning process in solving chemical problems. Based on these criteria, a person can be categorized as a critical thinker or not critical thinker. The criteria levels used in this study refer to the research that has been done by Siswono (2009), Kurniasih (2010) and Pujiastuti & Kurniasih (2012) and Rasiman & Kartinah (2013). This research seeks to formulate the levels of critical thinking ability of students in solving chemistry problems.

The research problem is how the levels of critical thinking skills students majoring in Chemistry Education UNNES in solving chemical problems. The research objective is to describe the students of Chemistry Education UNNES in their level of critical thinking ability in solving chemical problems. The level of critical thinking abilities can also be used as guidelines for assessment of students 'critical thinking abilities in learning chemistry and material consideration of designing a model or learning strategies to improve students' critical thinking abilities.

METHODS

Based on a qualitative approach in this study, all the facts both written or spoken human data from sources that have been observed and other relevant documents that are described accordingly are then studied as brief as possible to answer the problem. The research data is the level of critical thinking abilities of students in solving chemistry problems. These are arranged in discrete levels i.e., 0, 1, 2, 3, 4, based on indicators of Ennis critical thinking and assessment standards by Paul & Elder.

The data source is the second semester students of Chemistry Education UNNES in the academic year 2014/2015. Subject selection techniques with the snowball method means that the next subject is done after the election results obtained from the analysis of the subject beforehand, if there is no subject that occupies a level, it then carried out repeatedly to obtain the aimed subject.

Problem-based Learning (PBL) is used as a means to level critical thinking skills in solving chemical problems in materials about Acid-Base. PBL is ended with a written test to obtain a level of critical thinking ability based on the draft level of critical thinking that has been made. Researchers as the main instrument, so that at the time of data collection in the field, researchers were participating during the research process and actively following the activities of research subjects related to data collection. Problem of critical thinking test level is used for the selection of research subjects in accordance with the characteristics sought, and selected students who are able to communicate their thoughts orally and in writing and have uniqueness in the answers. The interview is required to obtain in-depth information and support of what has been obtained from the written test. Interviews conducted on two subjects specified for each level of critical thinking skills . Analysis of data from interviews conducted with the reduction step, the exposure of data, drawing conclusions from the data collected and verifying these conclusions. Data analysis was performed using The Constant Comparative Method.

The validity of this research is viewed from in terms of content validity, construct and empirical (internal). The validity reviews the accuracy of the theories that are used as reference material, the accuracy of the material that is used to measure the level of students' critical thinking, problem given has a level of difficulty and requires reasoning. The construct validity reviews the accuracy or logic thought of the level of

critical thinking developed (hypothetical theory), clarity of questions, understandable / easy to grasp its meaning, does not give rise to a double interpretation, actually measuring the critical thinking abilities. The empirical validity is indicated when the level of critical thinking developed in accordance with the reality on the observed ground, the suitability of the points of problems to identify aspects of critical thinking (Paul & Elder, 2007).

Reliability is complied if the findings are based on a theory that the current data collection give identical results or "equal" (consistent) with the results of previous theories have been formulated. The researchers did permanent comparative analysis to determine the reliability of the theory findings, (Moleong, 2009), for example by comparing a category of specific data with other specific data categories in order to get a category that has the same characteristics and fixed. A permanent category is the generated theories.

By giving weight or value for each answer (either from tests or interviews), the researchers were able to establish the degree of achievement obtained by each student, so that it can be determined the level of quality of critical thinking.

accuracy in the composition / construction issues like the

RESULT AND EXPLANATION

Stages for phasing Critical Thinking level

The procedures for phasing critical thinking level is as follows:

1. Determining the early theory (critical thinking level draft) which is based on theoretical review and is supported by empirical data.
2. Validating critical thinking level draft to the expert level to determine the construct and empirical validity according to the theory developed.
3. Pre-research to prove the presence of critical thinking level
4. Revising critical thinking draft based on the result of the pre-research
5. Collecting data to determine the presence of critical thinking level ability in solving chemistry problem based on the hypothetical theory developed.
6. Performing analysis with constant comparison method to find out the reliability of phasing the critical thinking ability which is then formulated (Rasiman and Kartinah, 2013 & Kurniasih, 2010).

The draft of critical thinking ability level that is composed intuitively based on the indicators of Ennis Critical Thinking (1996) with Paul & Elder standard assessment is in the Table 1.

Table 1. Draft of Critical Thinking Ability Level (CTAL) of Students in Chemistry Problem Solving

Critical Thinking Indicator	Assessment Standard	Critical Thinking Ability Level 4	Critical Thinking Ability Level 3	Critical Thinking Ability Level 2	Critical Thinking Ability Level 1	Critical Thinking Ability Level 0
Formulating problem issues	Clear	√	√	√	√	-
	Logical	√	√	√	√	-
	Meticulous	√	√	√	√	-
Revealing the facts needed to solve the problems	Exact	√	√	√	√	-
	Accurate	√	√	√	√	-
	Broad	√	*Limited*	Limited	Limited	-
Choosing arguments	Logical	√	√	√	-	-
	Relevant	√	√	√	-	-
	Accurate	√	–	-	-	-
Detecting bias based on different point of views	Relevant	√	√	-	-	-
	Accurate	√	–	-	-	-
Determining a result of a decision taken as a statement	Precise	√	√	-	-	-
	Deep	√	*less*	–	-	-

Based on the draft of critical thinking ability level imposed on the pre-research class, students are grouped into each level according to the characteristics that have been prepared. The result shows that there were 8 students whose critical thinking ability level is zero (CTAL 0), 8 students with Critical Thinking Ability Level 1 (CTAL 1), 4 students with Critical Thinking Ability Level 2 (CTAL 2), and 1 student with Critical Thinking Ability Level 3 (CTAL 3) and no one with Critical Thinking Ability Level 4 (CTAL 4). This result proves enough empirically that the appropriate level in the draft of CTAL exists, although there were none of the students who are categorized into the highest level. From the result of the pre-research, it was found that most of the students are categorized into CTAL 0 and 1. There were also students from level 0 whose criteria nearly met the criteria of level 1. However, on the indicator of formulating the problem issues, those students are less accurate and on the indicator of revealing facts needed in problem solving, only met one of the standard assessments.

Likewise, there are students who were categorized into CTAL 2-1. This means that those students do not meet the criteria of level 2 but they have been above the criteria of level one. This happens because there are one assessment standard or two in which the students do not meet. Moreover, there are also students who are categorized into level 3-2, because there are assessment standards of level 3 in which students do not meet, and have been above the criteria of level 2.

Based on the fact in a class of pre-study, the critical thinking ability level draft is then revised. The revision should be based on the fact, such as revising the CTAL 2-1 and 3-2. The revised draft is in the following table, Table 2.

Table 2. Improvements on Draft of Critical Thinking Ability Level

Critical Thinking Ability	Assessment Standard	Critical Thinking Ability Level 3	Critical Thinking Ability Level 2	Critical Thinking Ability Level 1	Critical Thinking Ability Level 0
Formulating problem issues	Clear	√	√	√	-
	Logical	√	√	√	-
	Meticulous	√/-	-	-	-
Revealing the facts needed to solve problems	Exact	√	√	√/.	-
	Accurate	√	√/-	√/.	-
	Broad	*Limited*	Limited	Limited	-
Choosing arguments	Logical	√	√	-	-
	Relevant	√	√	-	-
	Accurate	√	√/−	-	-
Detect bias based on different point of view	Relevant	√	-	-	-
	Meticulous	√	-	-	-
Determining a result of a decision taken as a statement	Exact	√	-	-	-
	Deep	*Less*	−	-	-

The improvement on CTAL draft is applied on the research class. This then is obtained the facts that most of the students are on level 0 and 1. Therefore, the phasing is only until level 3, and no more above. The characteristics of each level of critical thinking ability are the same with the characteristics on the improved draft. Thus, the phasing of critical thinking ability of chemistry students of Faculty of Mathematics and Science, Semarang State University is in the Table 2.

In this study, the phasing analysis of students' critical thinking is by exploring students' critical thinking which is integrated with chemistry problem solving. In the chemistry problem solving, students are actively engaged which is related to the indicators of critical thinking ability. With the problem solving steps namely understand the problem, make a plan, carry out a plan, and look back at the completed solution. Thus, students are expected to be well organized in solving the chemistry problem. In addition, the indicators of each critical thinking component is served in the following figure, Figure 1.

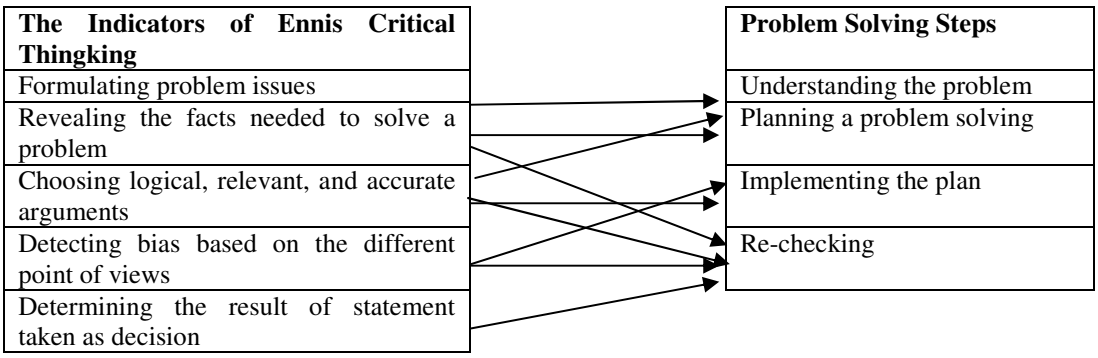

Figure 1. The integrated problem solving in critical thinking indicators

After implemented, the research step is in the form of the initial theoritical formulation (The draft of critical thinking). This draft is based on the theoritical review which is supported by empirical data. Then, validating the draft of critical thinking levelto the expert to determine the construct and empirical validity in accordance with the theory developed. The next would be carrying out the pre-research to porve the presence of critical thinking level, revising the draft of critical thinking based on the pre-research result, collecting data to find out the presence of the critical thinking ability level in Mathematics based on the hypothetical theory developed, analyzing the constant comparison method to find the reliability of critical thinking ability phasing (up to Critical Thinking Ability Level 0 and 3). Thus, this research results in hypothetical theory which is validated empirically as the following: Hypothetical theories of Critical Thinking Ability Level 0

Students are only able to (1) formulate the problem issues; (2) reveal(s) the facts needed to solve the problems; (3) select logical, relevant, and accurate arguments; (4) detect bias based on a different point of view; and (5) determine the result of a statement taken as a decision. However, all the assessment standards (clarity, accuracy, precision, relevance, logic, depth and breadth) are not completed. Students who achieve this level can be called as a *non-critical student.*

Hypothetical theory of Critical Thinking Ability Level 1Students are able to formulate the problem issues clearly and logically, and able to (1) reveal the facts needed to solve a problem; (2) select logical, relevant, and accurate argument; (3) detect bias based on different point of view; and (4) determine the result of a statement taken as a decision, although the assessment standards (clarity, accuracy, precision, relevance, logic, depth and breadth) are not completed. Students who achieve this level can be called as a *less critical* student.

Hypothetical theories of Critical Thinking Ability Level 2

Students are able to formulate the problem issues clearly and logically, able to reveal the facts needed to solve a problem correctly; and able to (1) choose a logical, relevant, and accurate argument; (2) detect bias based on different viewpoints; and (3) determine the result of a statement taken as a decision, although the assessment standards (clarity, accuracy, precision, relevance, logic, depth and breadth) are not completed. Students who achieve this level can be called as a *quite critical* student.

Hypothetical theory of Critical Thinking Ability Level 3.Students are able to formulate the problem issues clearly and logically, able to reveal the facts that are needed in solving a problem precisely, able to choose the logical and relevant arguments; able to detect bias based on different point of view; and able to determine the result of a statement taken as a decision appropriately. Students who achieve this level can be called as *critical* student. The data result from problem solving test and interview that have been obtained from the research class are then analyzed, and also the triangulation is applied to obtain valid data. The valid data is used to know about how the phasing of students'critical thinking ability in chemistry problem solving based on the Polya steps. The valid data are acquired as the Figure 2 and Table 3.

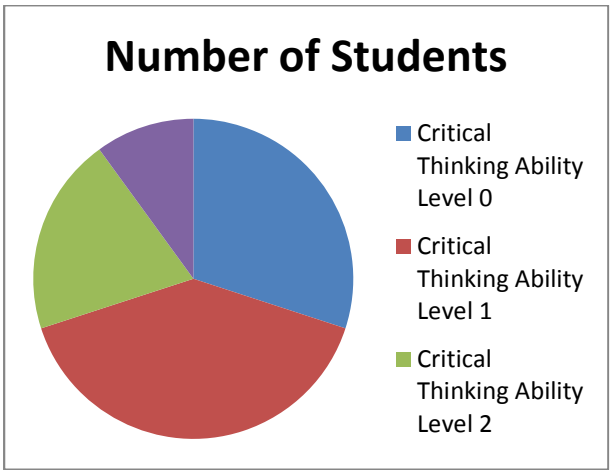

Figure 2. The number of students according to the level of critical thinking ability

Based on Figure 2. It appears that students tend to be in Critical Thinking Ability Level 1 and 2 while the number of students with Critical Thinking Ability Level 3 category is the smallest. The result of the analysis of students' Critical Thinking Ability Level in solving chemistry problems based on the Polya Steps is shown in Table 3.

The result shown on the Figure 2 and Table 3, it appears that the critical thinking process in **formulating problem issues**: on the step to determine what to know, subject is able to mention the data known and for the step of determining what to ask, subject can mention the problem issues, but still needs stimulus from the researcher. Critical thinking process in **planning the solving**: on the step of identifying the facts, the subject of the study has not been able to reveal the facts. On the solving-steps planning, the subject did not reveal the facts completely yet. In determining various types of compounds in solving the problem, the subject did not mention completely either.

Table 3 Students Critical Thinking Process based Critical Thinking Level and Polya solving

Critical Thinking Ability Level (CTAL)	**Understanding problem**	**Planning solving ide**	**Implementing the solving plan**	**Rechecking answer**
CTAL 0	Students are not able to formulate problem issues clearly, logically and meticulously	Students are not able to reveal the facts needed in solving problem precisely, accurately and broadly	Students are not able to reveal facts needed in solving problem, and are not able to choose logical, relevant and accurate arguments.	Students are not able to detect bias based on different point of view, and are not able to determine the result of statement taken as a decision precisely and deeply
CTAL 1	Students are able to formulate problem issues clearly, logically but not meticulously	Students are not able to reveal the facts needed in solving problem precisely, accurately and broadly	Students are not able to reveal the facts needed in solving problem, and are not able to choose logical, relevant and accurate arguments.	Students are not able to detect bias based on different point of view, and are not able to determine the result of statement taken as decision precisely and deeply
CTAL 2	Students are able to formulate problem issues clearly, logically and meticulously	Students are able t reveal facts needed in solving problem precisely, accurately and limitedly	Students are able to reveal the facts needed to solve problem, and also able to choose logical and relevant argument although less accurate	Students are able to detect bias based on the different point of view, and able to determine result from a statement taken as a decision precisely and deeply
CTAL 3	Students are able to formulate problem issues clearly, logically and meticulously	Students are able to reveal the facts needed in solving problems precisely, accurately and limitedly	Students are able to reveal the facts needed in solving problem, and abe to choose argument logically, relevantly	Students are able to detect bias based on the different point of view, and able to determine the result of a statement taken as a decision precisely yet less deeply

The process of critical thinking in **implementing the plan**: The subject of the study did not implement the steps completely and well-organizedly. In writing the equation and calculating the molarity, students still experienced difficulties. In problem solving plan, students initially faced difficulties as well. But, after thinking about some of the rules in acid-base theory, eventually they were able to calculate the pH of a mixture of acids and bases correctly. This is in accordance with the opinion of Hergenhahn and Olson (2009), who said that with more experience, one will adapt more easily to a situation that is increasingly numerous and varied.

If these aspects associated with indicators of critical thinking, the subject has not been able to formulate subject matter. Likewise, in planning the steps of solving, the subject has not revealed the facts completely and meticulously. In suggesting the

arguments, the subject has not mentioned in full form. This indicates that the knowedge of the students is still limited and they also still face difficulties in associating the information that presents in the problem, so that they were not be able to see the precise relationship between what is known and what is questioned.

The critical thinking process in **rechecking**: in the step to recheck the process and the result of solving chemistry problem, the subject of the study did not do it completely. Rechecking what is done with only re-reading it without doing any more analysis on the steps that have been developed. Although the subject said that they have rechecked by reading the each one of the steps, this did not include the analysis. They also did not relate to the knowledged they had. Therefore, the subject's understanding on the rechecking step is only defined as rereading. This made subject assumed that what has been done is completely in the correct order and completely right. If this statement is being related to the critical thinking process of the students, which is to evaluate the steps in solving a problem, this then means that the subject has not done the evaluation accurately either in the solving-problem steps or in the final calculation. The subject of the study has already believed in the problem-solving steps and the final answer just because they have reread. Likewise, the subject of the study has not made a conclusion based on the valid reason.

Thus, the phase of students'critical thinking process in problem-solving is as follows: (1) in implementing problem-solving steps, students did not do it meticulously and sistematically., (2) in applying the equation and the formula, there were a few of them who did not do it according to the plan made, (3) in the step of deciding and implementing, students did not do it systematically, and (4) the final result appears to be incorrect.

Thus, the steps of students' critical thinking process in implementing problem solving as follows: (1) in the step of the implementing problem-solving steps, students did not do it in detail or systematic, (2) in applying the formula and equation, students did some of the plan which are not according to the plan, (3) in the step of deciding and implementing, the order of the process is not systematic, and (4) the final result obtained is not correct.

The result in Table 3 is suitable with the opinion Krulik & Rudnick in Siswono (2009). It says that the lowest level of thinking is the memorizing skill (recall thinking) that consists of skill that is almost automatic or reflective. Thus, students with CTAL 0 or the lowest was limited to the ability to memorize without being able to understand the concept well. Furthermore, students with CTAL 1 are limited only in terms of understanding the issues. Elder & Paul (2008) stated that students who are categorized into CTAL 1 can be equated to the students who have the ability of beginning thinking. This refers to the thinkers who have just started to modify some thinking ability, but still with the limited insight. They lack a systematic plan to increase the capacity to think. In the case, students who are among the category of CTAL 2, are able to analyze their thoughts on an issue, but not in depth. For students who are classified into category CTAL 3, they could be categorized into accomplished thinking group. This refers to thinkers who are able to internalize the basic ability to think deeply, to think critically conscious, use high intuition with the wider insight.

The result of the reasearch above is in line with the the result of the research conducted by Kurniasih (2010). She found that most of the students' critical thinking ability in the first semester of Mathematics Education of Mathematics Departement, Semarang State University have critical thinking which is not critical, meaning CTAL 0, less critical which is in the CTAL 1. Also, the phasing of the critical thinking is only up to critical thinking at critical level, meaning CTAL 3. According to Pascarella & Terenzini (in Office of Outcomes Assessment, University of Maryland University College 2006), new college students have different level of critical thinking compared to senior students. Senior students who have advance thinking are able to apply the information well in solving complicated problems. They also are able to develop abstract thinking framework. Furthermore, the research done by Rasiman & Kartinah (2013) found that (1) students did not think critically (CTAL 0), means students could not clearly identify the issues as well as they could not develop abstract thinking framework. They also did not precisely and clearly reveal the initial knowledge, and they are also not able to plan problem solving, while less critical students (CTAL 1) could clearly identify the facts in the problem, but they were not able to to reveal the initial knowledge clearly and precisely, and they were also not able to plan the problem solving based on the initial knowledge, problem solving made by the students is still in the form of definition, concept, theorem, principle, and procedure which are less clear, less precise, less relevant, and less deep, at this level students could not yet differ whether a conclusion is based on valid logic. Adequate critical students could clearly identify the facts present in the problem, they also could clearly and precisely stated the initial knowledge (definition/theorem/data) which could be used in solving a problem which led to the ability of making problem-solving plan based on the facts given, initial knowledge, clear procedure, in solving the problem based on the concept and idea in the form of definition, concept, theorem, principle and procedure which were less relevant and deep. But they have not been able to distinguish whether a conclusion is based on valid logic. The students with CTAL 3 could identify the facts given clearly, could formulate the problem issues and could mention the facts/theorem/initial material needed to solve a problem. From the initial material, students were abl to plan and implement the plan that has been made relevant, meticulously and precisely.

CONCLUSION

Based on the data analysis, the facts found in this study are, the students'critical thinking ability level is limited up to critical level only (CTAL 3). In addition, most of the students show low critical thinking ability. The phasing of the critical thinking ability of students of Chemistry Education of Math and Science Department, Semarang State University in chemistry problem solving consists of critical thinking ability level 3 (critical), and critical thinking ability level 0 (not critical). Therefore, it is recommended that there is advance study in order to convince the result of the critical thinking ability phasing of the students in chemistry problem solving. The advance study is supposed to use various instrument to mesure the critical thinking ability, and the time taken for the study also should longer than the previous one. In addition, more efforts are needed to improve critical thinking ability of the students so that they are able to think in the higher leve consistently on all the dimensions of life.

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