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## Development of assessment instruments to measure critical thinking skills

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## Development of assessment instruments to measure critical thinking skills

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**Abstract.** Assessment instruments that is commonly used in the school generally have not been orientated on critical thinking skills. The purpose of this research is to develop assessment instruments to measure critical thinking skills, to test validity, reliability, and practicality. This type of research is Research and Development. There are two stages on the preface step, which are field study and literacy study. On the development steps, there some parts, which are 1) instrument construction, 2) expert validity, 3) limited scale tryout and 4) narrow scale try-out. The developed assessment instrument are analysis essay and problem solving. Instruments were declared valid, reliable and practical.

### 1. Introduction

According to commission of 2013 Curriculum, learning that must be implemented is the learning that can develop higher order thinking skills (HOTS) that included skills of problem solving, creativity, critical, and decision making. The achievement of high order thinking skills surely can't be separated from the assessment that must be implemented as integral parts of a learning process, to know the developing and students' learning result, and also to fix the learning. [1] [2]. It is needed test instrument, measurement and assessment that valid and reliable to assess critical thinking skills as an HOTS indicators that are expected as continue effect in Chemistry learning.

One of the motivations for the development Critical Thinking Skills assesment as a way to prepare students to be more successful in college and in the workforce, the underlying assumption being that students are not prepared currently to do so upon graduation from high school [3]. The transition from teacher-centered learning to student-centered learning should include complex goals such as fostering higher order thinking skills. In the past, the most common way of assessing students was the traditional form of a summative test. This sort of test usually examined content knowledge and did not assess higher order thinking skills [4]. In recent years, many researchers have reported about reforms that emphasized teaching for improving higher order thinking skills, such as asking complex questions, generating argumentation, constructing graph, and analyzing case-based articles through various innovative 'real world' activities [5] [6] [7].

Thinking critically is skill activity that can be done well or otherwise, and a good critical thinking will fulfill various intellectual standards, like clarity, relevance, accuracy, coherence etc [8]. Critical thinking skills is one of the thinking skills that defined by [9] as self-guided, self- disciplined thinking which attempts to reason at the highest level of quality in a fair-minded way. Ennis (in [10] gave a definition – critical thinking is thinking by argument and reflection by pressing the decision making



about what to believe and to do. The purpose of critical thinking is to make people away from wrong and rushed decision so it can be guaranteed. According to Costa (in [11] in thinking learning there are 3 ways, they are teaching for thinking, teaching of thinking and teaching about thinking. The same thing was stated by [12] in Foundation of Critical Thinking, critical thinking skills is an intellectual process about conceptualization, implementation, analysis, synthesis and evaluation actively and expert towards information that gained from observation, experience, reflection, thinking or communication as a guidance to believe and to do. This skills is marked by intellectual values that is universal, which are clarity, accuracy, consistency, carefulness, suitability, right evidence, a good thinking, deepness, width, and justice.

Evaluation to assess students' result was integrated done, which was not only by assessing what they had learnt, but also by assessing how the influence and students' skills in doing every steps in problem solving. Thus, the assessment began when the problem was laid until the final result assessment. The teacher assessed the students' skills of thinking, comprehension, and the successful in doing each steps of problem solving, how the students guide themselves to work and students' influence in team work.

Evaluation of critical thinking skills need measuring instrument that can draw perfectly the true condition. From the result of literacy study, it was gained some instruments to measure critical thinking skills on students, among others Academic Profile, California Critical Thinking Dispositions Inventory (CCTDI), Collegiate Assessment of Academic Proficiency (CAAP), Cornell Critical Thinking Test (CCTT), Critical Thinking Assessment Battery (CTAB) [13]. California Critical Thinking Skill Test (CCTST) is one of the instruments that developed by Facione since 1900 that was accurately believed to measure critical thinking skills of nursing students. Question items on CCTST reflected moderate critical thinking skills of nurses, Evidence- Centered Concept Map (ECCM) constructed and studied by [14] as instrument of computer based thinking skills assessment.

During this time, evaluation that was done by teachers/lecturers is generally the skills of reminding fact, concept or procedure. The teachers/lecturers often forget that the good evaluation is the evaluation that complete and can reveal every skills of assessed subjects [15]. Evaluation towards skills of presentation, performance evaluation and the skills of knowledge application on a product making, skills of synthesizing information and giving reason based on known information, often being ignored. From the learning result evaluation if that is implemented well it will form the critical thinking skill and creativity. These two skills underlying problem solving skill that was expected on students.

The developed assessment instrument were two test questions which were analysis essay test and problem solving test. Essay test was used because this type of test have characteristic to explore students opinion according to the skills they have, so the essay test supported the existence of critical thinking skills test subject. The used text to answer questions paid attention to problematic text criteria (text than can be exploited to think critically). Thus, those texts have criteria among other, (a) the content explain the things that is not suitable to real life/illogical, (b) the story content explanation is not followed by clear reason, (c) there is no continuity in describing a thing, (d) there is no appropriate between the content and the title, (e) given information in the text have particular purposes, and (f) lack of completeness in content explanation.

Developed cognitive instruments have provided the content and construct validity, reliability, practicality and good legibility. It can be seen from the test results of the test group, namely the expert assessment instruments, reading experts, practitioners, and students in the questionnaire assessment guidelines that have been given. Terms of construct validity of assessment instruments that have been developed include the portion of outline parts accuracy against the critical thinking concept. That aspect was obtaining the average score of 83.7%, so it can meet good construct validity. The developed assessment instrument includes aspects of critical thinking competencies which include, (1) developed the text interpretations, and (2) reflected and evaluated the text.

This is consistent with the theory expressed by Facione in [16] which said that critical thinking become objectives and assessment of self-regulation that results in interpretation, analysis, evaluation,

and conclusions. Ennis in [8] added that critical thinking is thinking that makes sense and reflective focusing to decide what should be trusted or do. Therefore, aspects of critical thinking skills include, aspects of interpret, reflect and evaluate the text in the developed assessment instrument.

The developed assessment instrument must meet the requirements of reliability. Aspects of reliability in the developed assessment instrument include instructions and rubric assessment. The level of reliability of the developed assessment instrument was good qualified. It can be seen from the test results to the group test on the reliability aspects of the assessment instrument. Instruments of thinking skills, not only emphasizes on understanding concepts but rather on aspects of the synthesis, analysis and evaluation, so that it has a relatively low constancy [17] [1] [18] Reliability with an alpha value above 0.6 then declared reliable. By referring to the reality on the field and the opinion of experts about the very need for the availability of raw instrument of critical thinking skills, especially in chemistry learning before it is implemented, then the problem solved in this research is to develop a valid and reliable standard instrument of critical thinking skills in chemistry learning.

## 2. Methods

The study was conducted in State Senior High Schools in Semarang Regency, Indonesia. This type of research includes Research and Development (R & D), referring to the [19] which is added to the needs of research. In this study, assessment levels differed according to the revised version of Bloom's [20] is at an intermediate, apply, and the three higher levels of Bloom's (analyze, evaluate, and create) require higher-order cognitive skills [21][22]. The taxonomy was originally designed to be a cumulative hierarchy where mastery of the higher levels of the taxonomy were prerequisite to performance on higher levels[20].

Aspects of critical thinking skills is composed of indicators according to [18] which includes: focus the questions, ask and answer questions, identify the assumptions, analyzing arguments, defining the term and consider a definition, consider whether the source is trustworthy or not, make and determining the consideration, observe and consider the report of observation, determine course of action, inducing and consider the results of induction, and interact with others. Likewise for aspects of problem-solving ability is composed of indicators namely the students are able to identify the problem, stating a causal connection, able to apply the concept in accordance with the problem, curious, able to create charts or images to solve a problem, explain some possibilities as a solution, open-minded, make decisions, able to work carefully, unwilling to speculate and able to reflect on the effectiveness of the problem-solving process.

In the first step of the development phase is an expert validation, validation is conducted in the form of content and construct validity of assessment instruments both test and non-test. According to [23]; [1], stated that the thinking skills instrument should have the good construct and content validity before used. Therefore, the expert validity becomes an important element to start the development. Validation results declared as valid after conducted revision in writing and legibility, compatibility between indicators of critical thinking skills with test items, compatibility of Bloom revision cognitive taxonomy used on each test item, the accuracy of the concept, the accuracy of images used in test items, the accuracy of test items presentation in problem solving items, simplifying the use of scientific terms.

In the next step, the test items reliability testing in school was conducted at the pre-trial phase. The instrument was declared valid by expert and have a high reliability coefficient been tested on a limited scale of 13 students, the sample was taken by purposive sampling. The data was collected using research instruments in the form of expert validity sheet, questionnaires sheet, essay tests analysis and problem solving tests. Qualitative data processed using a simple presentation technique then conducted a categorization of test items reliability by using alpha Cronbach. To see the instruments practicality can be seen from the student and teachers questionnaire responses percentage which was higher than 80%.

### 3. Results And Discussion

The products developed are CTS based assessment in acid-base solution material. This assessment instrument was in the form of essay analysis and problem solving test items consist 14 5 questions with a rubric assessment for teachers, where the item tests were designed or developed in order to measure students' critical thinking skills while simultaneously measuring the indicators of learning that has been made in accordance with Competence Standard-Basic Competence (CS-BC). Essay questions have been proposed [24]; [25] for effectively capturing students' meaningful understanding of science concepts, and problem solving test used to develop students' scientific literacy and higher order thinking skills through context-based chemistry[26]. The research has been compiled test instruments to measure critical thinking skills is test description. Beside it contains a description of the situation, followed by a question that leads to certain indicators of critical thinking skills. This is in line with the opinion of [27], which is very appropriate description shaped test to measure students' critical thinking skills.

To find out the characteristics of a CTS-based assessment that has been developed, it was conducted a test towards the conformance aspects of the material content with CS-BC, the material content conformity with CTS indicators, legibility and attractiveness of assessment instrument, student response, and the response of teachers to the assessment instrument developed.

The initial stage in the CTS based development of assessment on acid-base solution material was the needs analysis or preliminary studies which included a literature study and field study. Literature study generated a learning device in the form of concept analysis, syllabus, and CS-BC mapping about acid-base material.

At the second stage the preparation of the product assessment based on material CTS acid-alkaline solution called draft 1. At this stage the first thing to do is prepare questions outline in accordance with CS-BC. Thus produced an outline in which there were basic competencies, critical thinking skills activities, indicators of student competence, questions and answers. Outline contained indicators of critical thinking skills and SBC curriculum indicators. In this case there were two question models namely the essay analysis test (EAT) and problem solving test (PST) models and so there were two different outlines. Beside the questions, there was a student activity observation sheet regard to the critical thinking skills for learning.

Based on the outline, conducted a preparation of essay analysis and problem solving test items as many as 15 questions. Each item has been designed to measure students' critical thinking skills to any learning indicators are formulated. Expert or experts who validate the instrument is a chemist, an expert in critical thinking skills and educational research experts and field practitioners to validate the contents namely the chemistry teacher of high schools in Semarang regency.

The validity result of essay instruments analyzes the acid-base materials was stated very valid for all test items by all the experts that have been validated. In preparing this evaluation sheets, each stage conducted repairs and improvements based on guidance/input from material experts and expert of evaluation.

**Table 1.** Results of Validity of Essay Analysis Test (EAT)

No.	Description	Validator				Percentage (%)	Validation Criteria	Information
		1	2	3	4			
1	Instruction Aspects: Instructions of students' critical thinking skills instrument is clearly stated	3	3	4	3	87.5	Very Valid	Slightly Revised
2	Scope of Problem Aspects: The formulation of a logical test items (realistic)	3	3	4	4	100	Very Valid	Slightly Revised
	Conformity of assessment instrument content with critical thinking indicator	4	4	4	4	100	very valid	No revisions
	Conformity of assessment instruments with KD	4	4	4	4	100	Very Valid	No Revisions
	Items according to the level of critical thinking skills	3	4	3	3	87.5	Very Valid	No Revisions
3	Aspects of Language: The formulation of the sentence of communicative test items.	3	3	3	3	75	Valid Enough	Revision

The validation results of an acid-base materials problem solving instrument was stated very valid for all items by all the experts that have been validated. Problem solving test instruments can be used for research. Validation of a questionnaire was conducted by critical thinking skills expert and educational research experts. The results of the questionnaire validation declared valid seen by the scores given by experts.

Table 2. Results of Validity of the Problem Solving test

No.	Description	Validator				Percentage (%)	Validation Criteria	Information
		1	2	3	4			
1	Instruction Aspects: Instructions of students' critical thinking skills instrument was clearly stated	3	4	4	3	87.5	Very Valid	No Revisions
2	Scope of Problem Aspects: The formulation of a logical test items (realistic)	4	4	4	4	100	very valid	No revisions
	Conformity of assessment instrument content with critical thinking indicator	4	4	4	4	100	Very Valid	No Revisions
	Conformity of assessment instruments with KD	4	4	4	4	100	Very Valid	No Revisions
	Items according to the critical thinking skills level	3	4	3	3	87.4	Very Valid	No Revisions
3	Aspects of Language: The formulation of the sentence of communicative test items.	3	3	3	3	75	Valid Enough	Revision

Table 3. Results of Validity of responses questionnaire

Validator	Total Points Earned	Category
Critical thinking skills Expert	18	Very Valid
Educational research Expert	18	Very Valid

The revised assessment form subsequently tested at State Senior High Schools in Semarang Regency, Central of Java. The trial is addressed to the chemistry teacher and 30 students of class X. For teachers a questionnaire given on various aspects of conformity assessment based on CTS with CS-BC and CTS indicators as well as interviewed the teacher's response to the developed CTS based assessment.

Measurement of the essay analysis test and problem solving tests reliability performed by using Alpha Cronbach. The results of the overall reliability of the essays test instrument of acid-base analysis declared as reliable with a coefficient of 0.71. The reliability of the test instrument problem solving



declared as reliable with a coefficient of 0.79, thus concluded otherwise reliable instrument with very high reliability criteria for the essay analysis and problem solving tests item. Instruments or products which declared as reliable in the trial will be continued on a limited test phase. The results of the reliability test limited scale of the test instrument essays acid-base analysis revealed reliable with a coefficient of 0.74 with high reliability criteria. Instrument problem solving test reliability declared as reliable with a coefficient of 0.82, thus concluded instrument declared as reliable with very high reliability criteria.

All the results related to the items under study indicate that properly designed objective questions are valid and reliable tools for assessing students' meaningful understanding of acid-base concepts. This finding supports the suggestions [28]; [29] about the effectiveness of the conceptual questions on assessing aspects of their understanding.

The assessment instruments practicability related to the ease of assessment instruments, this aspect includes the appearance and layout of the assessment instrument, part of the contents of the assessment instrument, and applicability of assessment instrument. The look and layout of the assessment instrument lies in the content, presentation, and graphic. Student responses viewed using a questionnaire distributed after the end of the study. Data can be shown in Table 4.

**Table 4.** Students' Response toward Critical Thinking Skills Assessment Instrument

Category	many Students	Proportion
Very high	2	2/40
High	27	27/40
Enough	9	9/40
Low	2	2/40

The results of student responses on the implementation class showed that the student response was high, evidenced by from 40 students 27 students gave high response, 2 students responded very high, and the rest was sufficient and low. It showed a positive response from the students about the use of the instrument of students' critical thinking skills. This may imply that the developed critical thinking skills instruments assessed as practical. The use of adequate assessment, such as performance tasks, even during early stages, such as pre-service programs rather than just in professional development in-service programs.

The teacher's response is given to the development of students' critical thinking skills instrument. Before responding, teachers were asked to assess the developed instruments and then given a respondents' questionnaire after it. The result of the teacher's response to students' critical thinking skills instruments was discovered that the average response of teachers to use the instrument of critical thinking skills was 85%, thus concluded as practical instrument. The result of teachers' response to use the critical thinking skills instrument obtained a high response. This means that according to the high schools chemistry teachers in Ungaran city, critical thinking skills instruments was practical to be used due to in accordance with the school curriculum and graduation standards. Some teachers also want to learn to prepare the instrument and apply it in the learning process.

At the third stage, the data of product practicality. From the trial against the practicality aspect of the assessment instrument with a pilot group overall the average feasibility achieved the percentage of 83.33%, so that the instrument can be categorized as met the good assessment practicality aspect. And the fourth stage, the legibility data of products. From the trial of aspects of the assessment instrument

legibility with the pilot group overall the average feasibility achieved the percentage of 80.75%, so that the assessment instrument can be categorized as met the good legibility.

From the test results, also discovered some advantages of assessment instrument. In the aspect of the text selection can broaden the student knowledge as assessment instrument users, because the text used considering the aspect of reading situations and variations in the type of text. Those items presented were considering the aspect of critical thinking skills to be measured and the type of tests used to uncover these capabilities was vary. Assessment instrument was equipped with an attractive cover, introduction, assessment instrument components overview, questions introductory, and instructions. Nevertheless, the assessment instrument also has some drawbacks. In the aspect of text selection has not noticed the difficulty level of the text in the presentation, so that need for improvements in the designated text. At the critical thinking skills in the assessment instrument, evaluative questions were still lacking. In the aspect of language use was still lack of proper spelling, still contained the term on items that have an impact on student difficulties (as users of the product) to be difficult to understand the purpose questions on items. At the writing of the source of the text was incompletely presented. Fourth, readability assessment instrument associated with the use of language in the assessment instrument.

Below is a table 4 which showed the conducted limited testing results. The criteria tested in the sheet covering the aspects of conformity with the contents of CS-BC, and aspects of the appropriateness of the contents with CTS indicators, construction aspects, and aspects of CTS based assessment legibility on the subject material of acid-base solution. For the fourth aspects the average ratings was  $\geq 80\%$  with a very high category. So it can be said that the developed assessment sheet has been eligible to be tested. The feasibility assessment sheet showed that it has met the criteria of a good assessment sheet.

In Table 2, the results table limited testing has been done on 30 students and 1 teacher of chemistry. Average results obtained -rata is  $\geq 77\%$  with a high category for all four aspects: the suitability of the contents of the CS-BC, and aspects of the appropriateness of the contents with CTS indicators, construction aspects, and aspects of CTS based assessment legibility on the subject material of acid-base solution.

Furthermore, from the limited test results were also obtained students' response to the learning instruments developed. The results of student responses indicate that students are happy to development results instrument. It can be seen from the students' answers which showed a positive response to the instruments that have been developed. Students said that this instrument did not like the previous questions which only ask students to answer the questions based on concept or material. While the questions developed were not only asked students to answer based on the concept, but also to challenge the students to be able to give a simple explanation, build basic skills, concluded, elaborating and implementing strategies and tactics.

For the level of questions' difficulty, most students said that the problems provided were neither too difficult nor easy. Suggestions for improvement, they said that it needed to be better clarified for example the picture and the words used should not be too long. The teacher response to developed CTS-based assessment taken through the teachers responses at questionnaire on development of CTS based assessment on acid-base solution material can received the instruments that have been developed, according to the teachers, this instrument was good and can added knowledge and increased the exist test item types. This instrument also used critical thinking indicators thus be able to help the students to train students' critical thinking skills.

In these discussions presented a study of the CTS-based assessment characteristics that has been developed and constraints faced in the development of the developed CTS-based assessment. CTS based assessment characteristics on acid-base solution material was seen under the aspect of conformity with the CS-BC and can measured CTS students indicators. Based on the attractiveness aspects, CTS-based assessment has the attractiveness of the high level. The images used in the matter. Based on the legibility aspects, CTS-based assessment has a very high level of legibility. These assessments have high validity, both of the validity of conformity between the content of CTS-based assessment and the CS-BC and

also the validity of conformity between the SBC-based assessment content validation and SBC indicator. In the legibility validation test, this assessment also has a high validity. Developed CTS-based assessments aim to train students to be able to have good critical thinking skills.

Constraints faced when application of the assessment results namely this assessment for teachers in schools has not given questions to train students' CTS, so that students' answers were shorter and focus on the points in question, without giving a reason or an explanation of the answer, whether in the CTS-based assessment was demanding descriptive answers. This assessment should be made on going and can be completed in groups. Another obstacle is this assessment entirely in the form of essay questions that require the student's ability that includes conceptual and procedural knowledge.

Thinking skills is not an instant learning outcome that can be directly measured by two to three times of learning then declared as good or not. Based on the results of the research (Afcariono, 2008; Richmond, 2007; Woolf et al., 2005), said that it takes a process and not a short exercise to be able to change one's thinking skills.

### Conclusion

Based on the results, findings and discussion are obtained from the activities of preliminary studies, limited testing and test-wide scale, it has composed an analysis essay test (AET) instrument as well as problem solving test (PST), which was developed in the form of a description about its semi-open-ended is valid and reliable. Both types of instruments the test has been declared valid for all test items according to the expert assessment, and reliable with the reliability coefficient of analysis essay test instrument of acid-base of 0.74 and the problem solving test of 0.82. The developed Analysis Essay Test (AET) and Problem Solving Test (PST) also have to meet the criteria of practicality and good legibility and received a positive response from both students and teachers. It can be concluded that the assessment instrument developed has met the quality criteria of a good test, so it can be used as a form of alternative assessment instrument for teachers to uncover students' critical thinking skills. The two assessment schemes was developed based on a different approach, therefore, it can provide different information regarding students' critical thinking skills. A combination of the two assessment schemes offers the potential for multifarious evaluation of students' conceptual understanding and critical thinking skills.

However, since the developed assessment instrument yet include all the indicators and all the learning topics, it still needed further research on the development of critical thinking skills assessment instruments based on the other indicators whether the indicators propounded by Ennis or indicators developed by other experts, as well as another topics in chemistry lessons. Continuous support of the teachers was found as a critical. The importance of supporting the teachers is aligned, the use of adequate assessment, such as performance tasks, even during early stages, such as pre-service programs rather than just in professional development in-service programs.

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