

DEVELOPMENT OF STUDENTS' CRITICAL THINKING ABILITY ASSESSMENT INSTRUMENTS BASED ON MULTIPLE REPRESENTATIONS ON STOICHIOMETRY MATERIAL

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Abstract

This study aims to determine the results of the analysis of instrument requirements and the analysis of multiple representation-based stoichiometric material concepts used to measure students' critical thinking skills; the results of the feasibility test of the assessment instrument based on Aiken's index of expert validity; test results on the level of problem difficulty, reliability, discriminatory power and distractibility using Rasch modeling; the level of students' critical thinking skills as measured by the critical thinking ability assessment instrument; and student responses to the assessment instruments developed. The development model used in this study is a 4-D model consisting of define, design, develop, and disseminate stages. Based on the results of the needs analysis and the results of the material analysis, it was found that the assessment instrument for chemistry learning outcomes had not been able to measure students' critical thinking skills, and the stoichiometric material studied was following the basic competencies in the revised 2013 curriculum; assessment instrument for critical thinking skills based on multiple representations consists of 25 items. The results of the expert validation test are based on Aiken's index with high criteria of 0.81

and the results of the material validation index by teachers with medium criteria of 0.78. Empirical validation test with Principal Component Analysis (PCA) obtained 8 variance factors of 80.174% with the eigenvalues fulfilled. The test results are based on the level of difficulty of the questions with moderate criteria, the reliability of the test with Alpha Chronbatch is 0.75 with a good category, the discriminatory power of 76% with good category, and 60% of distractors function well. Analysis with Rasch modeling obtained 15 questions from 25 questions categorized as good to be used as a tool to measure students' critical thinking skills. The assessment instrument developed has a good ability to measure students' critical thinking skills, with 26.47% in the low ability category, 52.94% in the medium ability category, and 20.58% in the high ability category. Students' positive response to the use of critical thinking skills in the form of google form was 74.23%, with a good category. The product of the assessment instrument on the stoichiometric material developed is valid and meets the requirements for good quality questions, and can be used to measure students' critical thinking skills.

Keywords: *critical thinking skills, multiple representations, 4-D models, rasch models, stoichiometry*

A. Introduction

Education has a significant influence on the formation of a person's mindset, so that improving the quality of education must always be pursued. Education has entered the reform era 4.0 with acceleration in increasing knowledge and extraordinary information. In this 21st Century, education has an important role in ensuring that students can learn effectively, innovate, choose good information, and survive by using life skills (Zaenal A, 2017).

Zivkovic (2016) that the primary basis for success in the 21st Century is to have high-order thinking skills, one of which is critical thinking skills, because global competition is increasing, so students are expected to face real-world problems effectively.

Chemistry lessons in the 21st Century have goals with 4C characteristics, namely communication, collaboration, critical thinking and problem solving, creativity, and innovation thinking (Ekin et al., 2019). This is following the research results conducted by 250 researchers from 60 world institutions members of the ATC21S (Assessment & Teaching of 21st Century Skills), grouping skills in the 21st Century into 4 criteria, one of which is the way of thinking (Zivkovic, 2016).

Thinking ability uses the mind to look for an idea and understanding in making decisions, thinking about solutions, exploring ideas, and considering things. Thinking ability is divided into two parts, namely low-order thinking skills (LOTS) and higher-order thinking skills (HOTS).

One of the abilities that students must develop in the future is the ability to think critically (Susilowati, 2018). Critical thinking is logical and reflective thinking that emphasizes deciding what to believe or do responsibly (Hetii Patmawati, 2011). In this case, critical thinking ability is a high-level ability in processing the mind to find, explore ideas, and make a decision from a problem.

According to research by Harjo et al. (2019) regarding the Program for International Student Assessment (PISA) survey, the facts on the ground stated that of all participating countries, Indonesia was in the sixth-lowest rank. This indicates that students in Indonesia are still at a low cognitive level. Another field finding by Susilowati et al., in the research reviewed from The Trends in International Mathematics and Science Study (TIMSS), states that the international average score is 500, meaning that Indonesia is still below the international average because it has an average score on the science achievement of 398. Meanwhile, the PISA and TIMSS research requires a question instrument involving critical

thinking skills in working on the problem. The average score still in the low category in the PISA and TIMSS research indicates that students in the category of critical thinking in Science subjects are low, including in chemistry subjects. The results of research by Prihatini et al. (2016) support the fact that students are better able to work on memorization questions without mastering the concept.

Teachers can choose to train and determine the level of students' higher thinking skills by using the HOTS (Higher Order Thinking Skills) assessment instrument that raises critical thinking skills. According to research by Prasetyo and Dewi (2016), teachers are required to develop students' critical thinking skills in the assessment process. This is because critical thinking requires students to be able to make rational decisions with the reasons indicated through thinking skills. The Ministry of Education and Culture (2017) statement reveals that a collection of higher-order thinking questions is an instrument for measuring thinking skills consisting of levels C4 - C6, namely analyzing, evaluating, and creating.

The main factor that causes students' low critical thinking ability is the lack of effective assessment and evaluation instruments to measure students' higher-order thinking skills (Ghani et al., 2017). Applying higher-order thinking skills in the knowledge aspect affects students' critical thinking skills (Nurhayati & Ningrum, 2016). Students need to improve critical thinking skills, especially the ability to analyze and create, so that students' creativity in science increases (Saido et al., 2015). Therefore, an assessment instrument is needed to measure students' higher-order thinking skills, one of which is critical.

The chemical concept discussed in the research is stoichiometric material. These stoichiometric forms of matter are macro and real, i.e.,

what can be seen, touched, and smelled; submicro, namely atoms, molecules, ions, structures, and reactions stoichiometric equations; and symbolic, namely representational symbols, formulas, equations, molarity, molality, mole concepts, manipulation and mathematical graphs (Li and Arshad, 2014). To understand chemistry at the Multiple Representation level, students must connect one level to another or integrate these levels because these chemical representations are complementary (Jaber and Bou Jaoude, 2012). The main function of Multiple Representations in student learning complements cognitive processes, limiting interpretations between representations and building students (Prahani et al., 2016). Learners can understand the concept of learning as a whole with Multiple Representations (Nieminen et al., 2011).

The right type of test used in testing students' critical thinking skills is a reasoned multiple-choice test (Kusuma et al., 2017). Because the assessment in the form of multiple-choice reasoned can answer convincing statements on the answers that have been chosen by students (Istiyono et al., 2019), reasoned multiple-choice questions have advantages such as only one correct answer, so for that reason, students must have scientific evidence to choose the correct answer (Suparno, 2013).

This research was conducted with implications for obtaining a valid and reliable assessment instrument in assessing students' critical thinking skills and students' achievement of learning indicators. Both educators and researchers can take advantage of this opportunity to develop an efficient critical thinking ability assessment instrument. Based on the description above, the researcher is interested in conducting research entitled "Development of a Student's Critical Thinking Ability Assessment

Instrument based on Multiple Representations on Stoichiometric Material.”

B. Method

This type of research is oriented towards Research and Development (R&D). The research and development model applied is the 4-D (four-D) model developed by Thiagarajan, which consists of 4 main stages, namely: (1) defining, (2) design, (3) development (develop), (4) Disseminate (Thiagarajan et al., 1974). The product produced is an assessment instrument for critical thinking skills (Critical Thinking) based on Multiple Representations with Google Forms on Stoichiometry material.

The research was conducted at the Harapan 1 Private High School (SMAS) Medan. The choice of this place was based on reasons and considerations because this school had never conducted a similar study, and it was still rare to use an assessment instrument for critical thinking skills in chemistry subjects. The selection of locations used as research is limited by considering locations that are easily accessible to research.

The research time has been carried out starting from February to May. The stages of the research are carried out through 4 stages, and the implementation is carried out online (online) through the google form and communication with WhatsApp groups and google meet

C. Finding and Discussion

This research was conducted at SMA Swasta Harapan 1 Medan at the end of May 2021 in class X MIPA for the academic year 2021/2022 with a total sample of 59 students. In this study, the development of an instrument for assessing students' critical thinking skills based on multiple representations of stoichiometric material was carried out.

In this study, the development was carried out using a 4-D (four-D) model consisting of 4 main stages, namely (1) defining, (2) designing, (3) developing, and (4) distributing (Disseminate) developed by Thiagrajan. The development process for this instrument begins at the definition stage, namely analyzing relevant research studies, reviewing material concepts, reviewing the literature, and interviewing the chemistry teacher for class X MIPA 2 at SMAS Harapan 1 Medan, namely Mrs. Devi Ratnasari, S.Pd, Based on the results of interviews it was found that some students were still not used to solving critical thinking skills questions, but some other students were able to answer critical thinking skills questions because they had been given a stoichiometry e-module even though many students answered at level C4.

The next stage designs, which is the first stage in designing a product for the critical thinking ability assessment instrument. In simple terms, the instrument begins with the selection of KD and the determination of indicators on the stoichiometric material consisting of C4 (analyzing), C5 (evaluating), and C6 (creating) and is based on multiple representations consisting of sub-microscopic level, macroscopic level, mathematical level and level symbolic. According to the chemistry syllabus, the next step is to determine questions based on basic competencies (KD), which consists of 13 basic competencies (KD) in stoichiometry learning. KD 1 is one question C4, KD 2 is one question C4, KD three is one question C4, KD 4 is one question C5, KD 5 is four questions consisting of three questions C4 and one question C6. KD 6 consists of four questions consisting of two questions C4, and two questions C5, KD 7 as many as one question C5, KD 8 as many as one question C5, KD 9 as many as five questions consisting of three questions C4 and two questions C5, KD 10 as many as one question C5, KD 11 as

many as one question C5, KD 12 has one question C5, and KD 13 has three questions consisting of 1 question C4 and two questions C6. The question papers determined according to the basic competencies (KD) are designed based on multiple representations and answer keys and reasons for proof. In this case, the reason for the proof is done so that students are encouraged. In this case, the reason for the proof is that students are encouraged to think critically in answering the problems in the questions and not just answer. Next, a peer review was conducted by 2 colleagues. So that the results obtained are that there are still some writing errors in the critical thinking ability assessment instrument that was developed. This peer reviewer review is carried out to minimize errors in making assessment instruments. According to Liu and Chai (2009), peer reviewers can help researchers know and realize the advantages and disadvantages of an article and improve the quality of the content of the questions and the ideas of the questions to be developed.

The third stage is development (develop). The assessment instrument developed has passed two stages at this stage, namely the assessment of theoretical validation and empirical validation. Theoretical validation is carried out by expert judgment, namely material expert lecturers, linguist lecturers, and expert lecturers on evaluation and assessment, as well as validation of chemistry teachers from public and private. Based on the results of the validation analysis by lecturers and expert teachers, the Aiken index for material experts is 0.74 with medium criteria, linguists with 0.89 with high criteria, evaluation and assessment experts are 0.80 with high criteria. Material experts, the chemistry teacher, has an average of 0.78 with moderate criteria. The expert validator's assessment of the critical thinking ability assessment instrument based on multiple representations still needs improvements in

terms of material aspects, construction aspects, and language aspects to obtain a good instrument that respondents easily understand. In comparison, the results of expert judgment on each item obtained an average Aiken index of 0.81, which is included in the high category. So it can be concluded that all of the 25 questions submitted are valid and can be used later to test the validity of the item empirically.

Before conducting empirical validation, you must first test the readability of the instrument by online chemistry students and teachers. Due to the situation that is still a pandemic, the readability test and question assessment test are carried out online. This readability test is the basic thing to what extent the test questions developed can be understood and understood by the respondent. Dewi and Arini (2018) stated that the readability test was carried out to find out the material or language developed in the questions so that students could use the questions to understand the material contained in the instrument questions. After that, the revised instrument was rearranged based on the suggestions and comments developed so that the questions would be ready to be used for empirical validation tests.

The empirical validation was analyzed using the Rasch model and was carried out via google form by testing the revised instrument. In empirical validation, the Rasch model is used for testing to obtain varied results because the validity of the instrument can use various criteria so that the instrument carried out can be more reliable with the results (Othman, 2014). In this case, the validity instrument uses the Rasch Model analysis because of its better consistency (Jusoh, 2018). The advantages of using Rasch modeling compared to other methods are because it has a classical theory that provides linear measures with equal intervals and

performs an appropriate estimation process (calibration), the ability to predict missing data (missing data), can detect model inaccuracies,

Based on the analysis results from Rasch modeling, it is known that the critical thinking ability assessment instrument based on multiple representations to measure students' critical thinking skills provides accurate, consistent, and proven results that reveal one psychological construct (unidimensional = 47.5%), namely the assessment instrument to measure students' critical thinking skills. The quality of the product in the test results obtained from the results of the instrument trial. The trials that have been carried out include item validity, test reliability, item difficulty level, discriminatory power, and distractors. The results of the analysis of the student's critical thinking skills based on multiple representations are presented in Table 4.19.

Table 1. Results of Quality Analysis of Critical Thinking Ability Assessment Instruments

No	Test Characteristics	Analysis Results	Information
1.	Theoretical Validity	0.81	Height (Valid)
2.	Empirical Validity	20 items fit	The items that were discarded were items 4,16, 5, 14, 23.
3.	Test Reliability	0.75	Well
4.	Difficulty Level	+2.99 -2.76	Hardest Problem Easiest Question
5.	Distinguishing Power	76%	Well
6.	distractor	60%	Works well

Based on Table 1, it can be concluded that the critical thinking ability assessment instrument developed has high validity, sufficient reliability coefficient, and a moderate level of difficulty. Distinguishing power can distinguish students' thinking abilities, and distractors function

well. The analysis results show that 15 items of critical thinking ability assessment instruments based on multiple representations were developed and used for product implementation in the form of measuring critical thinking skills of students of class X MIPA at SMAS Harapan 1 Medan. The assessment instrument for critical thinking skills based on multiple representations consists of 15 questions consisting of 7 questions C4, 5 questions C5, and 3 questions C6, while the multiple representation aspect consists of 8 submicroscopic questions, 4 macroscopic questions, 1 mathematical question,

The last stage is dissemination (disseminate). Because it is still in the pandemic stage, the distribution of the product is carried out online via google form to measure the level of critical thinking skills of students in class X MIPA 2 at SMAS Harapan 1 Medan as many as 34 students. Furthermore, the distribution results of this product were analyzed using the Rasch/Rasch model. The Rasch model is an application that can be used to evaluate an instrument to measure the instrument's ability or the respondent by showing that the item is related to a person's ability to carry out an assessment (Sumintono and Widhiarso, 2015).

The analysis results for the multiple representation-based thinking ability assessment instrument show that students' ability level is students' critical thinking is categorized as good enough, and only some have less ability because they have a logit value above 0, namely -1.00 to +3.26 logit. However, in this case, students' ability still needs to be improved. The results of this study are in line with the results of Kusuma's research (2017), showing that the critical level thinking assessment instrument as an effective learning assessment is used to measure and train students' critical thinking skills. Students' critical thinking ability is categorized as low because the implementation of learning is carried out online because

it is still a pandemic through google forms that can be accessed using a laptop or smartphone. Although there is an online face-to-face between researchers and respondents using the Google Meet application, sharing information through WhatsApp groups, as well as e-modules that are uploaded and explained on the Edmodo application, some students still find it difficult to answer questions due to the absence of repeating or discussing e-modules again, or during the work, it seems careless, this can be seen the results of the students' reasons for proving in the comments on the google form only seem to give original reasons, and there is no upload of documents on the reasons for proving the questions posed.

Other factors are the lack of students' understanding of the material, not accustomed to working on critical thinking skills based on multiple representations, being less thorough in working on questions, incomprehension in reading the meaning of the questions. However, some students still find it difficult to answer questions due to the absence of repeating or discussing the e-module again, or during the work, it seems careless, this can be seen in the results of student proof reasons in the google form comments only seem to give original reasons, and there are no uploads Document the reasons for proving the question posed.

Based on the results of the implementation of critical thinking skills, the analysis of the achievement level of the critical thinking ability indicators of students from the highest to the lowest sequentially is an indicator (C4) with a logit value of -1.00 to +3.26, and evaluating indicator (C5) with a logit value of -1.50 to +2.92. The indicator creates (C6) with a -2.05 to +0.00. This shows that the average student's ability has moderate ability seen from the logit scale because they can answer the analytical question (C4). Some can answer the C5 question but are still lacking in answering the creation question (C6). So that students' knowledge in

answering questions about critical thinking skills still needs to be improved and obtained on the C4 indicator (analyzing) of -1.06 to +1.86, the evaluating indicator (C5) with a logit of -2.64 to +1.65, and the creating indicator (C6) with a logit value of -2.25 to +0.73. While similar research on the results of Lailly and Wisudawati's (2015) research shows that the higher-order thinking skills tested on the chemistry National Examination questions to students can only represent the cognitive level completeness in the analysis stage (C4).

While the results of the student response questionnaire to the critical thinking ability assessment instrument consisted of 8 indicators, indicator 1 shows that students gave a greater positive response, as much as 91.12%, than the instruments distributed presented the material they had learned. In the second indicator, students also gave a larger negative response, namely 73.52% that students had difficulties working on critical thinking ability instrument questions. In the third indicator, the questions and discourses on the instrument are clear and easy to understand and do not cause multiple interpretations. In the 4th and fifth indicators that students gave a positive response of 73.52% and 82, 34% that students can understand the question of the sentence and can understand chemical reactions and chemical symbols in the questions posed. In the sixth indicator, the positive response is greater by 70.54%, that the questions presented are interested in students to study the stoichiometric material more deeply, at the seventh indicator, the positive response is greater by 76.46% than the time provided in working on the questions sufficiently, and the eighth indicator of positive response is more than 91.17% that the questions presented can train students' critical thinking skills.

Overall, students provide a positive response to the assessment instrument for critical thinking skills based on multiple representations with an average positive response of 74.23% and an average negative response of 25.71%. In this case, it is appropriate and similar to the results of research conducted by Mutmainna (2018), which states that the criteria set for stating that students have a positive response must have at least a minimum of 50% positive response the total number of question items.

Meanwhile, to overcome so that the ability of students can be improved again with the teacher often integrating students in the practice of critical thinking skills based on multiple representations because students' critical thinking skills can be achieved maximally, it takes a long time to get used to working on these questions.

Based on the results found in the field, most students are still few who can answer critical thinking questions. Some of the factors that cause it are (1) since the beginning of stoichiometry learning, students are not introduced to multiple representation-based questions (2) Less optimal learning is given or received by students because of online learning, (3) E-modules are given to students. Students as learning supporters are not maximally studied by students (4) Lack of trained students to work on critical thinking questions, (5) Low interest and seriousness of students to study and seek other information independently.

This finding is in line with Rizky Ananda's research (2020) that there are problems due to the learning section during the COVID-19 pandemic. Problems that arise include less effective learning situations, students' difficulties in understanding material, especially material that requires calculations and abstracts, and the limitations of students to access the internet in distance learning when signal interference occurs.

Therefore, to overcome the problem of the lack of critical thinking skills of students, teachers, researchers, or other parties related to education, they can add learning media such as video media and stimulated questions based on multiple representations (Oktavia et al., 2021). In the learning process, it can be integrated with higher-order thinking questions, one of which is critical thinking in order to train students to be able to answer questions because critical thinking skills cannot be achieved in a short time, so it requires practice (Rozi et al., 2021).

D. Conclusion

Based on the results of data analysis and discussion, it can be concluded that:

1. The needs analysis results at the initial stage (define) showed that students were not accustomed to solving critical thinking skills at levels C4-C6. Furthermore, there are 13 KD related to the main material on the indicator questions at the material analysis stage, namely 12 questions C4, 10 questions C5, and 3 questions C6. And 12 submicroscopic questions, 6 macroscopic questions, 5 mathematical questions, and 2 symbolic questions.
2. The assessment instrument developed and analyzed with Aiken's index has an index value of 0.81 with a valid category and is suitable for use in research.
3. The results of the analysis with the Rasch Model, namely the empirical validity is obtained 20 items fit, and test reliability is 0.75 in the good category, the item difficulty level is in the moderate category, discriminatory power is 76% in good category and 60% distractors

function well. Thus, there were 15 critical thinking skills assessment questions based on multiple representations that were feasible to use, and 7 questions C4, 5 questions C5, and 3 questions C6 were obtained and included 8 submicroscopic questions, 4 macroscopic questions, 1 mathematical question, and 2 symbolic questions.

4. Based on the results of implementation, the level of critical thinking skills of students with e-modules given before the study was categorized as quite good, 26.47% of students had high abilities, 52.94% of students had moderate abilities, and 26.47% had low abilities with an average the logit value is $-1.00 - + 3.26$. As well as the analysis of the highest level of student achievement above the average ability of the indicator (C4) with a logit value of $+3.26$.
5. The analysis of student responses to the developed student critical thinking ability assessment instrument obtained an average of students who gave a positive response to the instrument of thinking questions of 74.23%, and the average student gave a negative response of 25.71%.

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