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THE DEVELOPMENT OF MEASUREMENT TOOLS FOR SENIOR HIGH SCHOOL STUDENTS' CRITICAL THINKING SKILLS IN CHEMISTRY

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Dr. A.A. Ketut Budiastra**

Abstract: Critical thinking skills are highly needed by senior high school students as they are the basic skills for understanding chemistry concepts. The evaluation tool was used to know the students' achievement in developing their critical thinking skill. The objective of this study is to develop and validate the measurement tool of students' critical thinking skill in chemistry. This research used Research and Development of Borg and Gall (1989) model that consists of three stages, i.e. introduction, development of product, and implementation of product. The location of study was at some senior high schools (SMA) in Cirebon City (Coastal area), Kuningan Regency (agricultural area), and Majalengka Regency (industrial area). The subjects in this study were students at second grade of some senior high schools majoring in natural science selected randomly totaling 1,314 people. The instrument used in this study was a graded multiple choice written test. Quantitative data in the form of students' critical thinking scores are processed using Anova test. Study results show that: Indicators of critical thinking accommodated in developing measurement tools for senior high school students' critical thinking in chemistry are: (1) elementary clarification (37.9%), basic support (3.16%), inference (55.8%), advance clarification (2.11%), and strategy and tactics (1.00%); (2) The characteristics of critical thinking test items developed met the requirement of good test items. In the concept of hydrocarbon, thermochemistry, and chemical equilibrium, discrimination index ranges $0.4 < DP \leq 0.7$, difficulty index ranges $0,1 < IK \leq 0.7$, coefficient of correlation ranges $0.2 < r_{xy} \leq 0.6$, and reliability ranges $0.4 < r_{11} \leq 1.0$; (3) Average senior high school students' critical thinking increased in Majalengka Regency at ($\bar{x}=29.2$), Kuningan Regency at ($\bar{x}=27,0$), and Cirebon City at ($\bar{x}=33,4$); and (4) Average students' critical thinking skill in the concepts increased on: chemical equilibrium at ($\bar{x}=21.13$), thermochemistry at ($\bar{x}=33.6$), and hydrocarbon at ($\bar{x}=33.7$).

Key words: critical thinking skills, measurement tools, chemistry concepts

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A. BACKGROUND

The main objective¹⁷ of science education is to prepare students to understand the concepts in science and to improve their thinking skill. Science education has a lot to do to develop high quality thinking skills, one of which is the critical thinking skill. Science education system should help students reach the objective of developing a number of concepts and meaningful conceptual systems, develop a free, creative, and critical thinking, and improve their ability to apply their knowledge to learn, solve problems, and make decision.⁷ *Science education should help students to develop the understanding and mind they need to become compassionate human beings able to think for themselves and face life head on. It should equip them also to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital”* (Rutherford and Ahlgren, 1990)

One form of quality thinking is⁹ critical thinking. Critical thinking is reasonable and reflective thinking focused on deciding what to believe or do (Ennis, 1991). A critical thinker is someone who is good at reasoning, has tendency to believe and do in accordance with his/her reasoning. A critical thinker will be able to evaluate, differentiate, and decide whether a piece of information, other people’s ideas, or his/her own ideas are right or wrong. He/she also can find alternative solution for the problems he/she faces.

Critical thinking in teaching is developed with the assumption that children generally can attain some critical thinking skill and this skill in children will always develop. Critical thinking skill also can be taught and learned. As the implication of this assumption teachers need to develop a learning process by developing learning models / designs that are implemented in the classroom in such a way so that they can arouse and motivate students. Teachers also need to make a scoring system that can develop students’ ways of thinking from just remembering facts to critical thinking. In line with its characteristics critical thinking needs to be trained, one way is by solving test problems which can develop students’¹⁹ critical thinking. Improvement in students’ critical thinking can be evaluated with a relevant measuring tool. The teaching-learning process and the scoring system have implication on the quality of education.

The fact is both local and national evaluation such as daily assessment, general assessment, simultaneous general assessment, study progress test, final evaluation test (EBTA), national final evaluation test (EBTANAS), and national exam (UN) still emphasize on mastery of



concept (Rustaman, 1995) by using a measurement tool such as paper and pencil test with multiple choice questions which measure very little high level of thinking. Zainul (2001) says that there is a tendency teachers construct test items of multiple choice which only measure aspect of remembering or the lowest level of cognitive aspect. The fact in the field shows that the evaluation system for promotion in one term / semester given in every school uses the measurement tool similar to that of National Final Evaluation Test (EBTANAS), so that teachers are not motivated to make a more critical teaching – learning process.

To know ³the level of students' success in developing critical thinking we need a measuring tool that can measure this specific ability. Evaluation is an important factor in education as through evaluation we will know precisely where a student's position is within a certain time or certain activity.

Based on this opinion ²¹it is clear that critical thinking is included as the psychological characteristics of a person which can be classified into low, medium, or high, and this can be determined if there is a measurement with clear rules and formulas. Based on the pre-study currently there is no measurement tool that can measure ⁵high school students' critical thinking skills especially in chemistry.

³Basic test of critical thinking skills need to be developed in all topics. However there are some materials / topics in high school chemistry that can accommodate the needs of a thorough evaluation of the ability to think if we view it from the characteristics of the concepts contained in those materials. The three topics are the concept of thermochemistry, hydrocarbons, and chemical equilibrium. ³Critical thinking skills can be developed through thermochemical concept which is a concept of abstract critical attributes but it has concrete examples, and the concept of chemical equilibrium which is a concept based on a principle, and the ³concept of carbon compounds that has the characteristics of a concept that involves the depiction of symbols.

Based on the above description it is necessary to develop a measurement tool for ⁸critical thinking skill of senior high school students in chemistry which can determine the qualifications of the students' critical thinking in chemistry and its application on a wider scale. The purpose ¹¹of this study is to develop and validate the measuring tool for senior high school students' critical thinking in chemistry so that a validated measuring tool for ⁵senior high school students' critical thinking in chemistry can be produced.



B. PROBLEM FORMULATION

The above background has become the basis for formulating the main research question which is “What measuring tool can be developed to measure **5** senior high school students’ critical thinking skill in chemistry?”

The above research question can be elaborated further as follows:

1. What indicators of critical thinking skill can be accommodated in **13** the development of measuring tool for senior high school students’ critical thinking skill in chemistry?
2. How is the characteristic of the questions used as a measuring tool **5** for senior high school students’ critical thinking skill in chemistry concept developed?
3. How is the measuring tool **5** for senior high school students’ critical thinking skill in chemistry implemented in the three different regions of this research with different environmental characteristics?
4. What is the result of the implementation of the measuring tool **5** for senior high school students’ critical thinking skill in chemistry based on the three different characteristics of the chemistry concepts?

C. RESEARCH METHOD

3 The research used “*Research and Development (R&D)*” design adopted from Borg and Gall (1989). The subjects of this research were senior high students of grade X and XI science in Cirebon municipality, Kuningan Regency, and Majalengka Regency drawn with *multistage stratified sampling* totaling 1,314 students. The instruments used in this research consist of: (1) Analysis of thermochemical concept, carbon compound and chemical equilibrium, (2) Items of measuring tool for critical thinking in thermochemical concept, chemical equilibrium, and hydrocarbon compound, (3) Critical thinking skill measuring tool in the form of graded multiple choice test items, (4) Software for validating test items, discriminating power, index of difficulty, and reliability, (5) expert validation column. Data collecting technique was done through written test. Data analysis in this research include deciding instrument validation for whole test items in the instrument, analysis of test items which include deciding validation for each test item in the instrument, deciding index of difficulty for each test item in the instrument, deciding the discriminating power in each test item of the instrument, deciding instrument reliability as a whole.

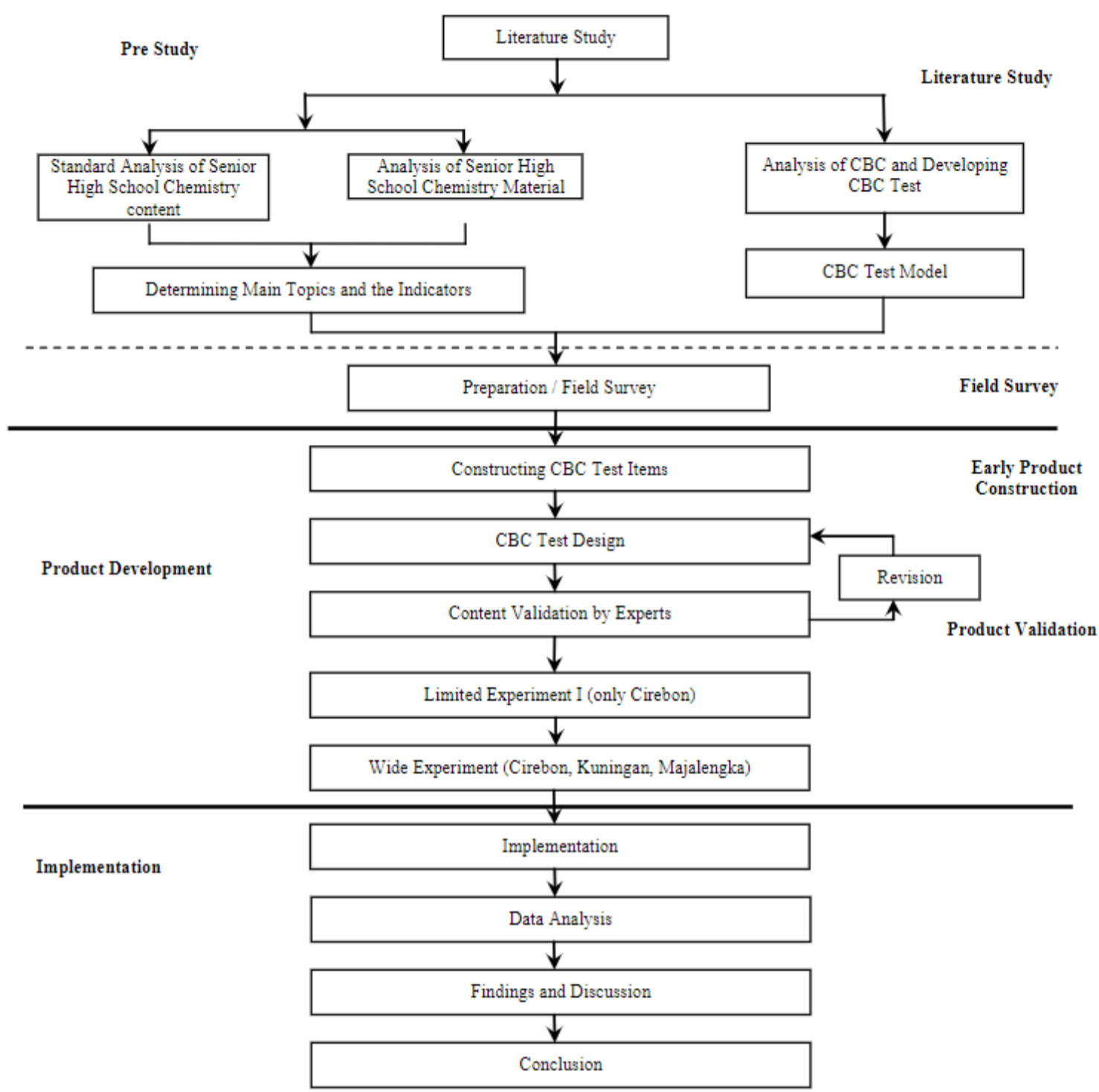


Illustration 2

Research Flow Chart

D. RESULT AND DISCUSSION

1. Indicators of Critical Thinking Skills Accommodated in the Development of Critical Thinking Measurement Tool

Indicators of critical thinking skill developed in the construction of the measuring tool for critical thinking skills are: elementary clarification (37.9%), basic support (3.16%), inference (55.8%), advance clarification (2.11%), and strategy and tactics (1.00%).

Indicators of critical thinking skills developed in the concept of hydrocarbon are: elementary clarification 16 questions (40%), basic support 2 questions (5%), strategy and tactics 1 question (2.5%), inference 19 questions (47.5%), and advance clarification 2 questions (5%).



Indicators of critical thinking skills developed in the concept of thermochemistry are: *elementary clarification* 8 questions (26.7%), *basic support* 1 question (3.3%), and *inference* 21 questions (70%). Indicators of critical thinking skills developed in the concept of **chemical equilibrium** are: *elementary clarification* 12 questions (48%), and *inference* 13 questions (52%).

2. Experts' Validation

Validity test was done for two things: content and empirical validation. Validity test was entrusted to three experts, one expert in measuring tools, one expert in critical thinking and one expert in chemistry concept. The number of experts involved was odd as it was intended to facilitate decision making when analyzing assessment result from the experts. Validation was done based on professional consideration by a group of experts who validated the content of the test items either from their material, test construction, or the clarity of the language used. Content validation was meant to know what are the components of validating components from the experts are: (1) the language is easily understood, (2) conformity of questions with the lesson material, (3) conformity of questions with the indicators, and (4) need of critical thinking stages.

This validation resulted in a set of suggestions from the experts to improve mistakes in writing, use of inappropriate language, and unconformity between indicators and test items developed.

3. Characteristics of Test Items

a. Limited Test

Result from test I (limited) in the form of empirical validity, reliability, level of difficulty, and discriminating power of the test items. The results of the three tests are as follows:

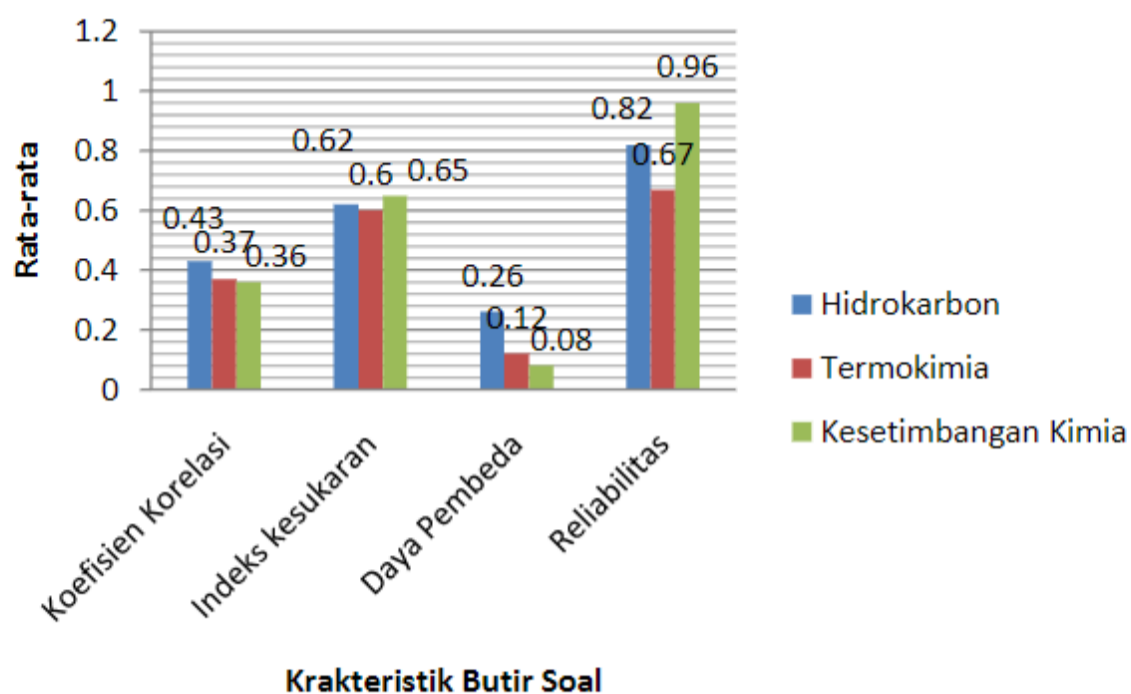


Chart 3

Characteristic of Test Items for Critical Thinking Skill in the Limited Test

Based on chart 3 above it is found that as a whole the test on the topic of hydrocarbon, thermochemistry, and chemical equilibrium has discriminating power at $0.0 < DP \leq 0.4$ (medium), difficulty index of test items at $0.3 < IK \leq 0.7$ (medium), average correlation coefficient at $0.2 < r_{xy} \leq 0.6$ (medium), and test reliability has adequately high consistency in measuring critical thinking skills.

b. Wide Test

Comparison of the characteristics of the test items for critical thinking skills among the three concepts of chemistry in test II (wide) in Cirebon Municipality, Kuningan Regency, and Majalengka Regency can be seen in the following chart:

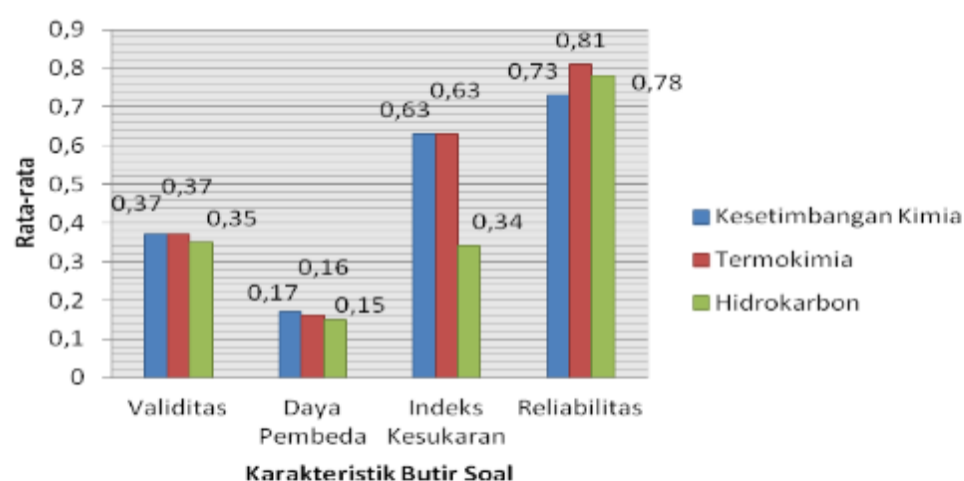


Chart 4

Comparison of the characteristics of the test items for critical thinking skill, Wide Test, Cirebon City

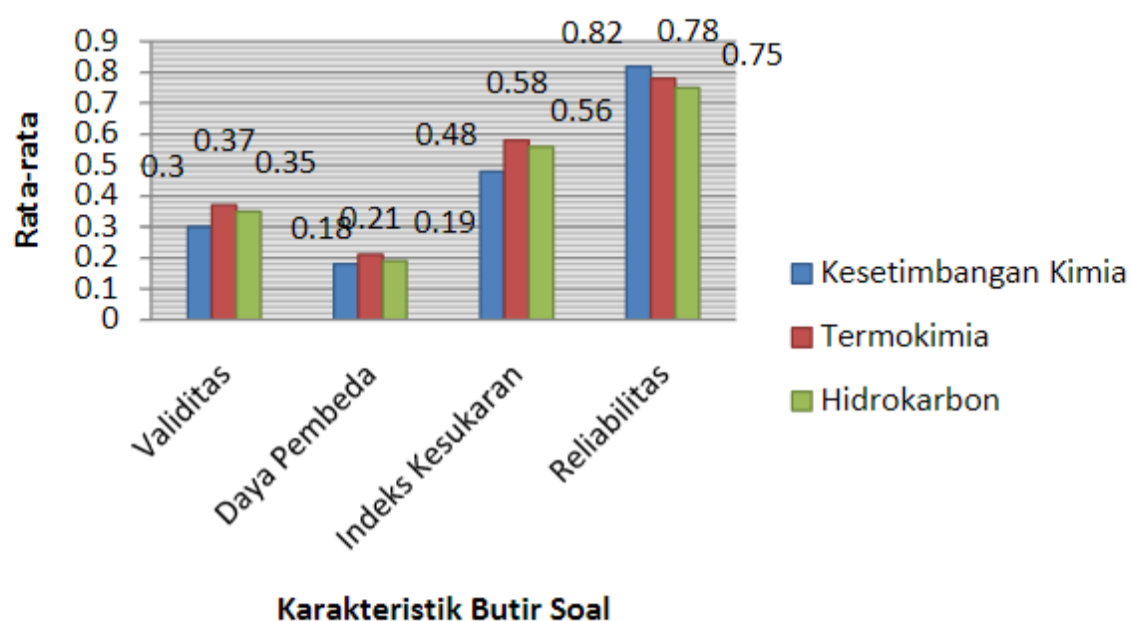


Chart 5

Comparison of the characteristic of the test items for critical thinking skill, Test II (Wide), Kuningan Regency

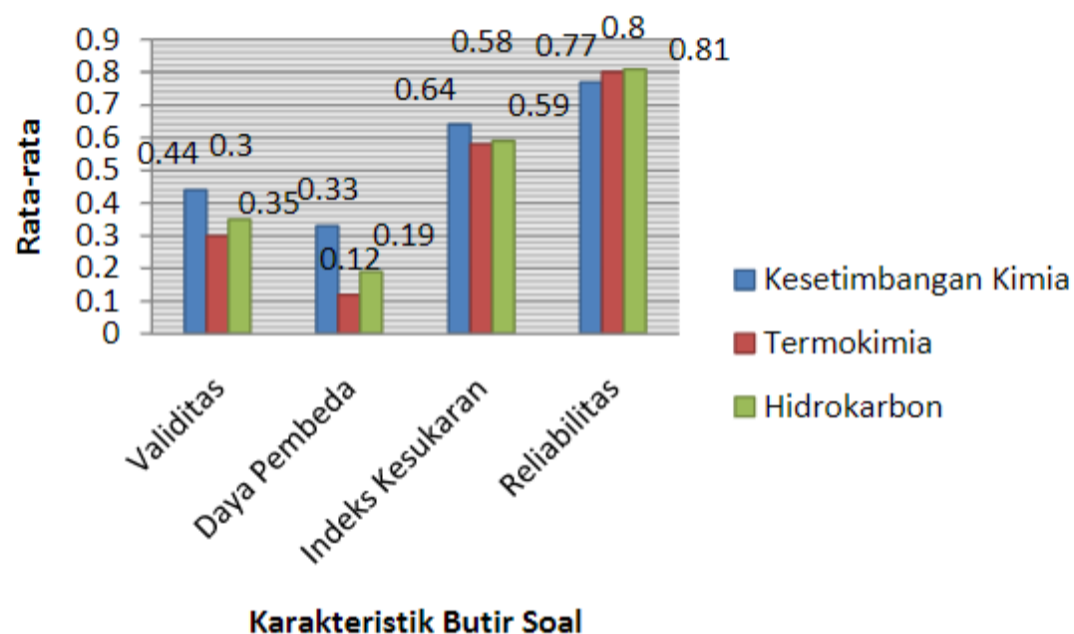


Chart 6

Comparison of the characteristic of the test items for critical thinking skill in the concept of Chemical Equilibrium, Thermochemistry, and Hydrocarbon Test II (Wide), Majalengka Regency

Based on the chart 4, 5, and 6 of the test II (wide) carried out in Cirebon city, Kuningan, and Majalengka regency as a whole the test on the topic of hydrocarbon, thermochemistry and chemistry equilibrium has high reliability so that it has consistency in measuring critical thinking skills, which means all test items developed can give the real picture of the critical thinking skills of the students.

4. Difference in the Average Thinking Skills of Senior High School Students Based on the Regions



Comparison of average critical thinking skills among the three different regions of Cirebon, Kuningan, and Majalengka by using the measuring tool developed can be seen in the following chart:

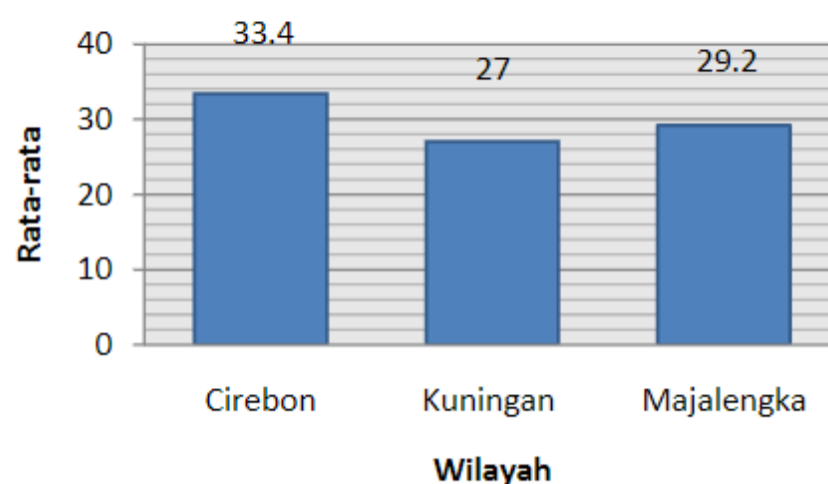


Chart 7

Comparison of Average Critical Thinking Skill among Senior High School Students of Different Regions

Based on the charts above it is shown that the average critical thinking skills of high school students moved down from Cirebon, Majalengka and Kuningan. The average critical thinking skills of high school students in the city of Cirebon is higher than Majalengka and Kuningan. And the statistical test (LSD test) revealed that the critical thinking skills of high school students who come from Cirebon are best compared with students from Kuningan and Majalengka.

This situation is in line with the general view in the community that sociology geography / culture affect the mindset / thinking skills of its people. Characteristics of Cirebon City community with the mindset of coastal communities is critical, dynamic, while characteristics of Majalengka community with strong cultures tend to trade more creative thinking as well as the characteristics of the Kuningan Regency which is an agricultural society is passive and practical, so that the average critical thinking skills of Kuningan students is lower than Majalengka and Cirebon.

5. Differences in average Student Critical Thinking Skills Based on Characteristic of the Concepts

Comparison of the average critical thinking skills of students based on the characteristics of the concepts by using a measuring tool developed can be seen in the chart below:

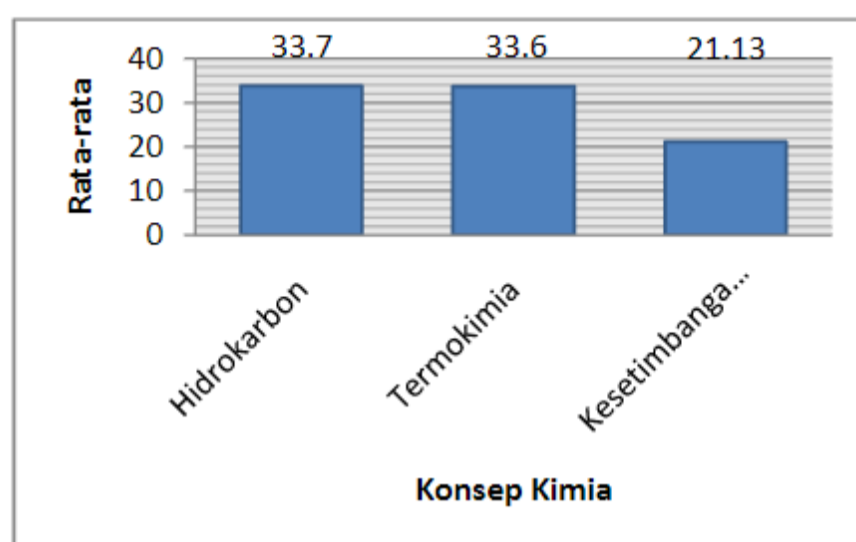


Chart 8

Comparison of Average Critical Thinking Skills of High School Students based on the characteristics of the concepts

Based on chart 8 above it is shown that the average critical thinking skills of students based on the characteristics of the concept moved down for hydrocarbons (33.7), thermochemical (33.6), and chemical equilibrium (21.13). The concept of hydrocarbons has the highest average than thermochemical and chemical equilibrium. This suggests that students' perceptions of test items of critical thinking skills vary in each concept. Differences in the characteristics of the concept led to different perceptions on the test items of critical thinking skills in the area of Cirebon city, Kuningan, and Majalengka regency.

The concept of hydrocarbons, thermochemistry, and chemical equilibrium has different characteristics. Hydrocarbons as a concept that involves the depiction of symbols and structures require high visualization abilities, thermochemical concept is a concept that is based on a principle requires strength in practicing and applying the principles of chemistry, and chemical equilibrium is an abstract concept but has a concrete examples requires the ability to think rationally high.

This suggests that the concepts of chemistry has different characteristics that can develop critical thinking skills. Dahar (1989) states that chemistry is made up of concepts in a network of proposition. In line with Dahar's statement that the concept has characteristics that are based on their attributes and has a hierarchy based on its inclusiveness (Herron, 1977).

6. Differences in average Student Critical Thinking Skills Based on Schools' Ranking in the concept of Hydrocarbon, Thermochemistry, and Chemical Equilibrium

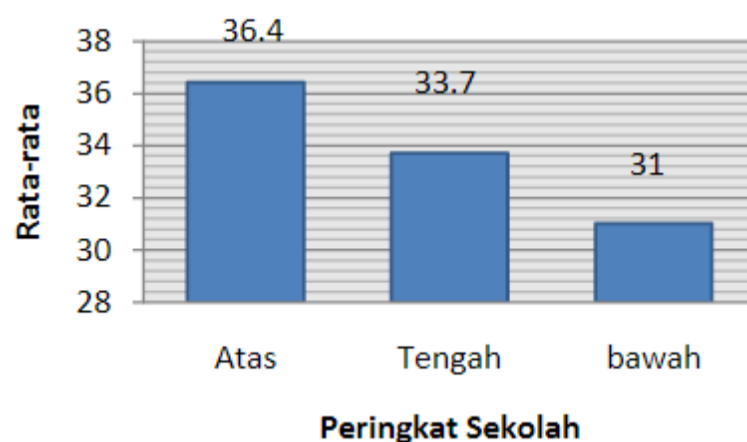


Chart 9

Comparison of Average Critical Thinking Skills of High School Students in the Concept of Hydrocarbon based on the schools' Ranking

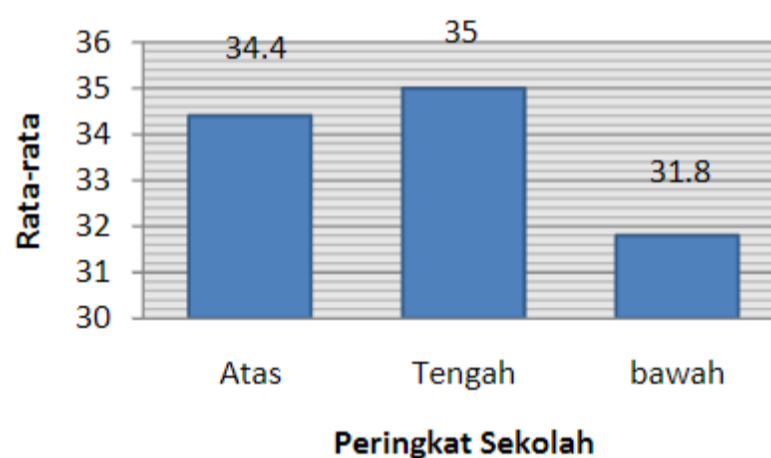


Chart 10

Comparison of Average Critical Thinking Skills of High School Students in the Concept of Thermochemistry Based on Schools' Rating

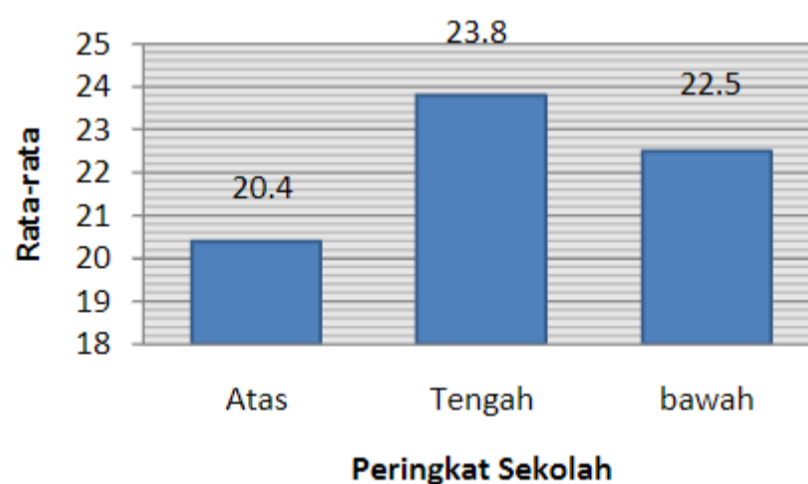


Chart 11

Comparison of Average Critical Thinking Skills of High School Students in the Concept of Chemical Equilibrium based on Schools' Ranking



Based on chart 11 above it can be explained that there is a difference in the students' critical thinking skills of the different school ranking based on the characteristics of the concepts. Difference in school ranking has an effect on the level of critical thinking skills, where school of the high rank is usually dominated by students with high intellect. Students with high intellect surely have high critical thinking skills too. Intellectuality has something to do with level of intelligence, and intelligence is correlated with critical thinking skills.

7. Differences in average Students' Critical Thinking Skills Based on Regions

Overall comparison of the test results on critical thinking skills based on regions can be seen in the chart below:

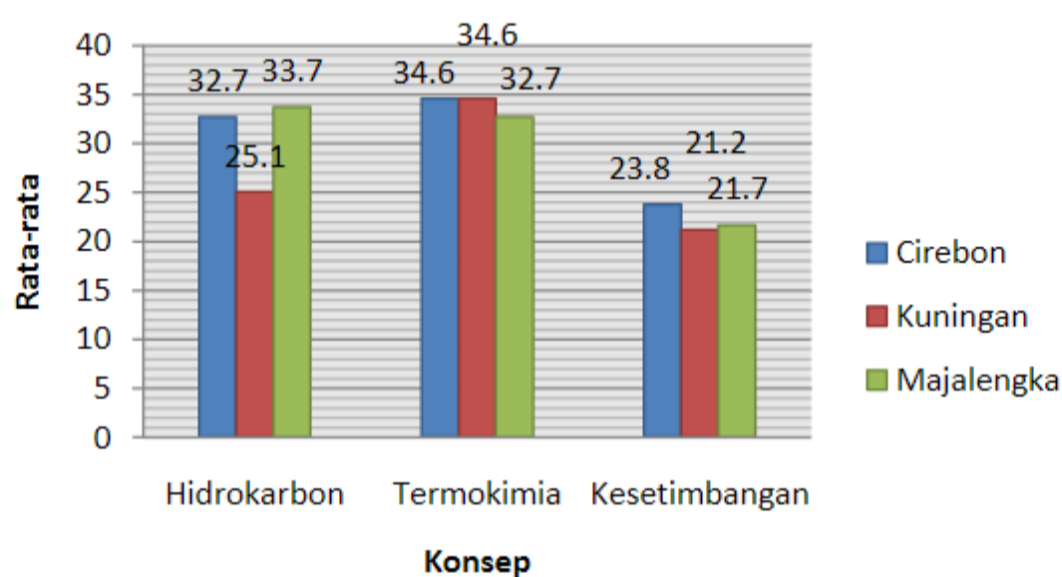


Chart 12

Comparison of Average Critical Thinking Skills based on Chemistry Concepts among Regions

Based on chart 12 above it can be explained that students' critical thinking skills in Cirebon city and Kuningan regency on the topic of thermochemistry are highest while students' critical thinking skills in Majalengka regency are highest on hydrocarbon concept.

On the concept of chemical equilibrium students in Cirebon city have higher critical thinking skills (averaged 23.8) compared to students in Kuningan and Majalengka regency. For hydrocarbon concept students in Majalengka regency have higher critical thinking skills (average 33.7) compared to students in Kuningan regency and Cirebon city. While on the concept of thermochemistry students in Cirebon city and Kuningan regency have the same critical thinking skills (average 34.6).

This suggests that students' perceptions on test items of critical thinking skills vary in each concept and each region of Cirebon city, Kuningan, and Majalengka regency. Differences in



the characteristics of the concepts and characteristics of the regions led to different perceptions⁶ on the test items of critical thinking skills in the area of Cirebon, Kuningan, and Majalengka regency.

E. ¹² CONCLUSION

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

1. The instrument used can develop students's critical thinking skills on hydrocarbon, thermochemistry, and chemical equilibrium concepts.
2. Chemistry teaching in senior high schools (SMA) can improve¹⁵ students' critical thinking skills using a measuring tool of critical thinking skills on the concepts of hydrocarbon, thermochemistry, and chemistry equilibrium with indicators of¹⁴ elementary clarification, basic support, inference, advance clarification, and strategy and tactics.
- 3.¹ Characteristics of the critical thinking skill test items developed meet the standar of good quality test. On the concept of hydrocarbons, thermochemical, and chemical equilibrium the discriminating power ranges $0.4 < DP \leq 0.7$, index of difficulty ranges $0.1 < CI \leq 0.7$, the correlation coefficients ranges $0.2 < r_{xy} \leq 0.6$, and reliability ranges $0.4 < R_{11} \leq 1.0$.
4. The measuring tool developed in high school chemistry teaching was able to distinguish³ critical thinking skills of students based on the characteristics of the concepts and characteristics of the region.
- 5.³ The average critical thinking skills of high school students increased from Kuningan regency (27.0), Majalengka (29.2), and Cirebon (33.4).
6. Average students' critical thinking skills increase from chemical equilibrium concept (21.13), thermochemistry (33.6), and the concept of hydrocarbons (33.7).

F. RECOMMENDATIONS

Several recommendations put forward from this research are:

1. Further research is needed by using the critical thinking skills index (scoring value).
2. Other researchers can develop another critical thinking skill measuring tool on¹ the concept of hydrocarbon, thermochemistry, and chemical equilibrium by using indicators of¹⁸ different critical thinking skills to enrich evaluation tool in the teaching of chemistry



3. Teachers should use the measuring tool of critical thinking skills in the teaching - learning process in order to enhance students' critical thinking skills.
4. Valid test items can be used as a measuring tool of critical thinking skills while invalid items should not be used as a measure of critical thinking skills, particularly test items number 24, 32, 34, 37, 39 in the concept of hydrocarbons (12.5%), numbers 1, 3, 5, 6, 8, 20, 27, 28, 30 in the concept of thermochemistry (30%), and numbers 3, 6, 14, 16, 18, 24 in the concept of chemical equilibrium (24%).
5. Chemistry teaching needs to be improved by applying teaching-learning models that can improve students' critical thinking skills.

G. IMPLICATION

For teachers who apply critical thinking skill model in their teaching-learning process, the measuring tool for critical thinking skills that has been developed in this study can be used as an appropriate evaluation tool especially ¹ in the concept of hydrocarbon, thermochemistry, and chemical equilibrium.

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