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CRITICAL THINKING SKILLS AND THEIR RELATIONSHIP WITH THERMOCHEMICAL LEARNING OUTCOMES OF GRADE 11TH STUDENTS

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Abstract

Critical thinking skills are key cognitive skills that include interpretation, analysis, evaluation, inference, explanation, and self-regulation. Thermochemistry topics include knowledge (products of science) and science process skills that to learn them require critical thinking skills. In addition, this topic can also be used to develop critical thinking skills. The purpose of this study was to analyze the critical thinking skills of grade 11 students and their relationship with their thermochemical learning outcomes. This study applies a correlational descriptive research design. The subjects of this study were 266 grade 11 students of SMAN 2, SMAN 8, and SMAN 9 Malang. Data collection is carried out using tests. This research instrument was developed by the researcher himself. The critical thinking skills test on Thermochemistry consists of 10 valid essay questions with a Cronbach Alpha coefficient of 0.82, while the thermochemical learning outcomes test consists of 15 valid multiple-choice questions with a Cronbach Alpha coefficient of 0.74. The results showed that the average score of students' thermochemical critical thinking skills was 67.64% and the average score of students' thermochemical learning outcomes was 76.19%. Correlation analysis using Spearman Rank Correlation showed that these two study variables were significantly correlated [sig. (2-tailed) 0.00 < 0.01] and in the direction of medium strength [relationship strength +0.261]. This shows that students who have good critical thinking skills tend to have learning outcomes as well and vice versa.

Keywords*: Critical Thinking Skills, Thermochemical Learning Outcomes*

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INTRODUCTION

Thinking skills include basic human needs. Every day people encounter life problems whose solution requires thinking skills. As an important part of thinking skills, critical thinking skills are considered one of the four learning skills of the 21st century (Erstad & Voogt, 2018). Critical thinking skills are also established as learning outcomes of the 2013 Curriculum (MoEC, 2016a) which is currently in force in Indonesia. The consequence of the placement of critical thinking skills as learning outcomes is the availability of critical thinking skills assessment instruments, relevant learning strategies, and theoretical foundations that show that critical thinking skills are related to learning outcomes. However, as far as our study is carried out, the availability of critical thinking skills assessment instruments, learning strategies to develop critical thinking skills, and theoretical foundations regarding the relationship between critical thinking skills and learning outcomes are still very limited.

Critical thinking is reasonable reflective thinking that is focused on making decisions regarding what to believe or what to do (Ennis, 2015). Critical thinking skills are mental processes that occur in processing information. Critical thinking skills help solve problems, make decisions, and think critically. Experts formulate a framework of critical thinking skills with different formulations. This study follows a critical thinking skills framework consisting of six skills, namely interpretation, analysis, evaluation, inference, and explanation, as well as self-regulation (Facione, 2020) (See Table 1).

Effective learning requires methods that are by the characteristics of the subject matter and approaches that are appropriate to the learning output (Hodson, 2014). The learning outcomes of interpreting, analyzing, evaluating, referring, and explaining skills, as well as self-regulation, require learning experiences that are relevant to these skills. Formally, the 2013 Curriculum applies a scientific approach, *an inquiry-based learning*, which consists of five student learning experiences, namely observing, questioning, trying, relating, and communicating (MoEC, 2016b). The learning experience of observing is relevant to the skill of interpreting, trying to be relevant to the skills of analyzing and referencing, associating relevant to the skill of explaining, and the experience of learning to communicate is quite relevant to evaluating and self-regulation. Nevertheless, this explanation needs to be supported by evidence from the analysis of students' critical thinking skills.

Table 1. Critical Thinking Skills Framework (Facione, 2020)

No	Skills	Sub Skills	Indicator
1	Interpretation	Explaining the meaning	• Clarifying the statement of an event; • Expressing the meaning of a question; and • Identify a statement.
2	Analysis	Wheezing identifies ideas and reasons	• Identify the reason for the claim of a statement; • Identify an event.
3	Inference	Making conclusions that are logical valid or can be correct right	• Identify and establish the elements necessary to draw reasonable conclusions.
4	Evaluation	Assess the credibility of a claim Assessing the quality of arguments	• Assess the credibility of a statement that is a person's perception, experience, situation, judgment, belief, or opinion.
5	Explanation	Presenting arguments	• Present and justify reasoning relevant to the evidence, concept, method, criteria, and context.
6	Self-regulation	Self-monitoring Self-correction	• Consciously monitor a person's cognitive activity, the elements used to monitor such cognitive activity, and the established results.

Thermochemistry is a branch of chemistry that discusses the thermal energy that accompanies chemical reactions (Effendy, 2017: 15). Thermochemical subject matter includes energy and heat, calorimetry and enthalpy changes, thermochemical equations, standard enthalpy changes (ΔH^o), mean bond energy, and reaction enthalpy changes (MoEC, 2018). This study material is closely related to natural phenomena that can be observed, measured, analyzed, inferred, and explained. In other words, the thermochemical subject matter is highly relevant to inquiry-based instruction learning experiences (MoEC, 2016b). Therefore, the thermochemical learning outcomes of students are not far from this analysis.

Previous studies have not shown the same relationship between critical thinking skills and student learning outcomes. In the context of nursing students, learning outcomes are not related to critical thinking skills (Shirazi & Heidari, 2019). In contrast, in the context of high school students and prospective students, learning outcomes are related to critical thinking skills (Akpur, 2020; Yang & Zhao, 2021). These results indicate that the relationship between learning outcomes and critical thinking skills is not absolute, it can be conditional. Therefore, it needs further research to confirm this conjecture. The high relevance between thermochemical study materials and the domains of critical thinking skills allows two constructs to be interconnected with each other.

Studying thermochemical constructs requires domains of critical thinking skills. On the contrary, studying thermochemical constructs can also be used to improve the skills of interpreting, analyzing, evaluating, referring, and describing, as well as carrying out self-regulation. Nevertheless, we have not found any research results that show a link between students' thermochemical learning outcomes and their critical thinking skills. The purpose of this study was to analyze students' critical thinking skills, their thermochemical learning outcomes, and the relationship between the two constructs.

RESEARCH METHODS

Research Design

This study applied a correlational design (Creswell, 2015) where researchers described the degree of relationship between two variables, namely critical thinking skills and thermochemical learning outcomes. This study is not an experimental study, the researcher does not give treatment to the subject of the study. The treatment has been received by students in the form of regular learning carried out by teachers of chemistry subjects.

Instruments

The study involved two instruments, a critical thinking skills test and a thermochemical learning outcomes test. Both were developed by researchers themselves. The critical thinking skills test is developed based on the critical thinking skills framework that has been developed by previous researchers (Facione, 2020) with

knowledge of Thermochemical content. This test consists of 10 essay-type questions; with details of 3 items about interpretation skills, 2 items about analytical skills, 1 item about drawing conclusion skills, 2 items about evaluation skills, and 2 items about making explanation skills. The evaluation of the test based on a trial of 143 Grade 11 students showed that: (1) the difficulty level of all items of the medium category of questions; (2) the difference of 1 item of fewer category questions, 1 item of sufficient category questions, and 8 items of good category questions; (3) all items of the category are valid; and (4) the Cronbach Alpha reliability coefficient is 0.82. This value is well above the minimum limit of the acceptable test reliability coefficient for the study, which is 0.5 or 0.7 (Taber, 2018; van Griethuijsen et al., 2015).

The learning outcomes test is developed based on the scope of knowledge (Basic Competencies 3.4 and 3.5) and skills (Basic Competencies 4.4 and 4.5) of the Minister of Education and Culture No. 37 of 2018 (MoEC, 2018). The learning outcomes test consists of 15 multiple-choice type questions with various cognitive levels (Anderson & Krathwohl, 2001). Questions number 1 and 5 represent the cognitive level of C1; question number 7 cognitive level C2; question number 4, and 8 cognitive level of C3; questions number 2, 3, 6, 9, 10, 12, and 15 cognitive levels C4; and questions number 11, 13, and 14 of cognitive level C5. The evaluation of the test based on the trial of 143 Grade 11 students showed that: (1) the difficulty level of 2 items of easy category questions, 12 items of medium category questions, and 1 item of difficult category questions; (2) the difference between 4 questions of sufficient value and 11 items of good value questions; (3) all items of the category are valid; and (4) the Cronbach Alpha reliability coefficient is 0.74, above the minimum value that can be used in research (Taber, 2018; van Griethuijsen et al., 2015).

Research Samples

The sample of this study was 266 grade 11 students of the Mathematics and Natural Sciences (Mathematics and Sciences) Program from SMAN 2, SMAN 8, and SMAN 9 Malang. The sampling of this study is *convenience sampling*. Researchers have difficulty obtaining samples as expected, namely *stratified random sampling*, because this study coincides with the COVID-19 Pandemic.

Data Collection and Analysis

Data collection is carried out in the form of midterm exams after students have experienced Thermochemical learning which is carried out using a scientific approach (*an inquiry-based instruction*) (MoEC, 2016b). In this way, it is expected that the student works earnestly so that the results describe his abilities. For analysis purposes, the correct answers of the learning outcomes test (multiple choice question type) are given a score of 1 and the wrong answers are given a score of 0. The final score obtained by students is determined based on their respective percentages of correct answers. While the critical thinking skills test (type of essay test) is assessed by *coding* where the wrong answer is given a score of 1, the wrong answer containing the truth is given a score of 2, the correct answer containing the error is given a score of 3, and the correct answer is given a score of 4 (Facione, et.al., 2011). The final score obtained by students is determined based on the percentage of correct answers of each student, both at the level of critical thinking skills and the level of the domains of critical thinking skills. The level of students' achievement and critical thinking skills were determined using the criteria as shown in Table 2 (Heng et al., 2014, 2015).

Table 2. The criteria of students' achievement and critical thinking skills (Heng et al., 2014, 2015; Muntholib et al., 2020).

Score(%)	Level
80.00–100.00	Excellent
60.00–79.99	Good
40.00–59.99	Moderate
20.00–39.99	Weak
0.00–19.99	Very weak

The correlation between critical thinking skills and students' thermochemical learning outcomes was analyzed using *the Rank Spearman* technique with the help of the SPSS for Windows Program. The results of the analysis describe the significance and direction of the correlation. Two variables are expressed to be significantly correlated when the significance of the correlation ≤ 0.01. The correlation of two variables is unidirectional when the correlation coefficient is positive and in the opposite direction when the correlation coefficient is negative (Creswell & Creswell, 2018).

RESULTS OF RESEARCH AND DISCUSSION

This survey involved 266 students in grade 11 of MIPA SMAN 2, SMAN 8, and SMAN 9 Malang for the 2021/2022 Academic Year who had studied thermochemistry. Figure 1 shows the average score of the respondent's critical thinking skills.

Figure 1. Average Score critical thinking skills of Thermochemical Material Students

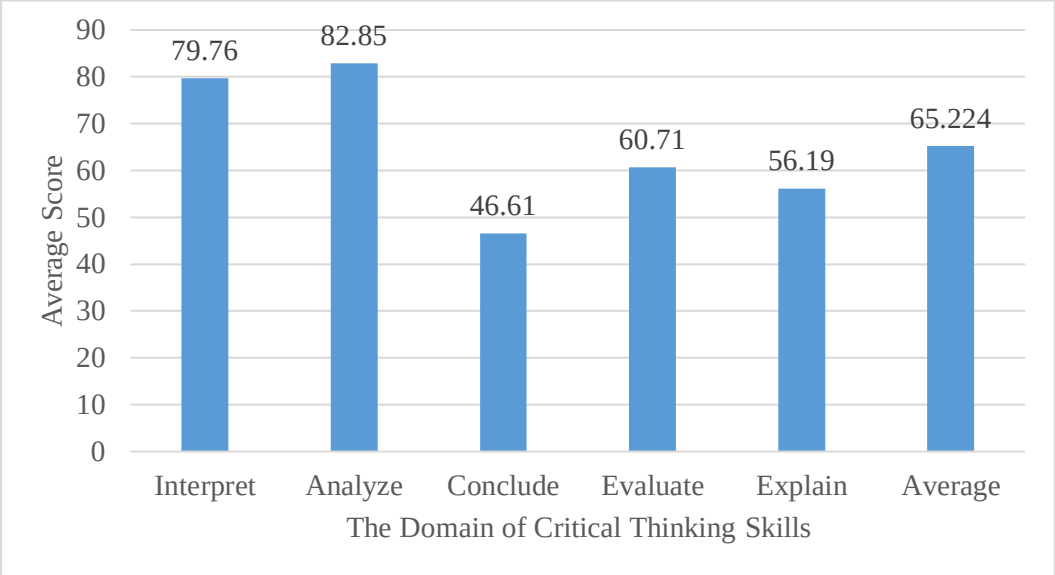

Figure 1. Average Score critical thinking skills of Thermochemical Material Students

Figure 1 shows that the average score of each shiva critical thinking skill domain is 46.61 – 82.85 with an average score of 65.22 (good category). The skill of drawing conclusions has the lowest score (46.61) in the medium category and the skill of conducting analysis has the highest score (82.85) in the excellent category. Figure 1 also shows that students can interpret ideas or ideas and analyze the statements or problems given properly. However, some students are still weak in drawing conclusions and making explanations.

Students' high proficiency in understanding/interpreting, analyzing, and evaluating as well as their weak skills in drawing conclusions and making explanations relevant to their learning experience. Respondents to this study received lessons with an expository approach that emphasizes conceptual understanding (Lazonder & Wiskerke-Drost, 2015; Maandig et al., 2017; Stockard et al., 2018). The main learning methods they received were lectures, demonstrations, videos, and verifiable practicums. Inference skills, drawing conclusions or making claims require the support of relevant knowledge and the skills of performing analysis. Meanwhile, the skill of making explanations requires understanding and the ability to utilize relevant knowledge, both conceptual and theoretical knowledge. These two cognitive skills are not trained in direct instruction so students can't have them properly. In detail, the student's skill levels for each critical thinking skill domain are spelled out as follows.

Interpretation Skills. Interpretation is the ability to understand and express the meaning of an experience, situation, data, event, rule, procedure, or criterion (Facione, 2020). Students' levels of interpretation skills were assessed using questions numbers #1, #2, and #3 (Attached). The average score of respondents was 79.75%. To be able to answer questions numbered #1 and #3, students must understand the difference between a system and an environment so that they can interpret the components of a universe, identifying the components of the system and the environment. Meanwhile, question number #2 assesses students' skills in interpreting changes in standard enthalpy. "Systems and the Environment" and "Standard Enthalpy Changes" are the subject matter of thermochemical topics so students can understand them well and can identify them in a context.

Analyzing Skills. The analysis is intended to identify inferential relationships among statements, questions, concepts, descriptions, or other forms of representation to express beliefs, judgments, experiences, reasons, information, or opinions. The level of analysis skills was assessed using questions numbers #4 and #5 (Attached). The average score of students conducting the analysis was 82.84%. To answer these questions, students understand the features of exotherm and endotherm reactions, relate them to chemical events, as well as give explanations.

Inference Skills. To do inference means identifying and taking the elements necessary to draw reasonable conclusions and make conjectures and hypotheses. Students' skills in inference were assessed by question number #6. The average score obtained by students is 46.61%. To answer question number 6, students must identify reactants and products to write down the thermochemical equation of the formation of $C_3H_8(g)$. Students can answer this question well if they can identify that $C_3H_8(g)$ is a reaction product, the molar masses of $C_3H_8(g)$, and $C(s)$ and $H_2(g)$ as reactants. The low skill of students in inference is due to: (1) to answer this question students need to identify and carefully calculate reactants and reaction products, and (2) students do not distinguish between thermochemical equations and combustion reactions.

Evaluation Skills. Evaluation is intended to assess the credibility of statements and the rationality of the relationship between statements. Students' skills in conducting evaluations are assessed with questions numbers #7 and #8. The average score of students in conducting the evaluation was 60.71%. To answer question number 7, students must understand the reaction between NaOH and HCl and why the reaction is said to be an exothermic reaction. As for answering question number #8, students must understand the concept of binding energy.

Skills to Create Explanations. Making explanations aims to state and justify bi-made reasoning based on correct analysis with convincing arguments. Questions numbers #9 and #10 assess the skills of making explanations. The average score of students is 51.69%. To answer question number #9, students must first conclude that the energy of the C-H bond of 392.5 kJ/mol is the average price and can explain that in the CH_4 molecule the energy of a C-H bond is affected by the presence of other C-H bonds. Meanwhile, in question number 10, students must explain how to bond energy can affect the exotherm or endotherm of a reaction.

A survey of students of SMAN 2, SMAN 8, and SMAN 9 Malang grade 11 MIPA for the 2021/2022 School Year, totaling 266 students who have studied Thermochemistry, showed that the average score of students was 76.19%. These results show that students' Thermochemical learning outcomes are relatively good. These results also confirm the efficacy of direct instruction in developing students' conceptual understanding (Cobern et al., 2010; Forbes et al., 2020; Stockard et al., 2018).

We also conducted a correlational analysis between students' critical thinking skills and their Thermochemical learning outcomes. Figure 2 shows the results of a correlational analysis of critical thinking skills with student learning outcomes conducted using the *Spearman Rank technique.* Figure 2 shows that sig. (2-tailed) 0.00 < 0.01 with a relationship strength of +0.261 (sufficient category). The results of this analysis show that critical thinking skills are positively correlated with Thermochemistry learning outcomes with moderate strength (Creswell, 2015). This means that students who have good critical thinking skills tend to have good Thermochemical learning outcomes and vice versa. This conclusion is supported by the character of the Thermochemistry subject matter which consists of natural phenomena whose data can be observed, analyzed, inferred, evaluated for validity, and explained with a theory that is easily understood by students. In other words, learning Thermochemistry requires critical thinking skills. On the other hand, students' learning experiences in learning Thermochemistry can also improve students' critical thinking skills.

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Correlations

			KBK	Hasil Belajar
Spearman's rho	KBK	Correlation Coefficient	1.000	.261**
		Sig. (2-tailed)	.	.000
		N	266	266
	Hasil Belajar	Correlation Coefficient	.261**	1.000
		Sig. (2-tailed)	.000	.
		N	266	266

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 2. Spearman Rank Technique Analysis Results

CONCLUSIONS AND SUGGESTIONS

A. Conclusion

Critical thinking skills and learning outcomes Thermochemistry respondents in this study were classified as good with consecutive average scores of 67.64% and 76.19%. Correlational analysis showed that the devotion of these two variables was positively correlated with moderate strength. This suggests that: (1)

Thermochemistry subject matter that can be observed, measured, analyzed, inferred, interpreted, explained, and evaluated can be used to improve students' critical thinking skills, and (2) critical thinking skills are required to study Thermochemistry.

B. Suggestion

According to the results of the study, we recommend that: (1) Thermochemical learning involves learning strategies that provide learning experiences to students to practice domains of critical thinking skills, for example, the combination of direct instruction with inquiry-based instruction, and (2) the development of learning strategies involving the components of direct instruction and inquiry-based instruction, and (3) experimental research is carried out to test the effectiveness of the resulting learning strategies in improving students' critical thinking skills.

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