Guided Discovery-Based Thermochemistry Modules To Enhance Critical Thinking Ability And Process Science Skills: Development And Experimental Results

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Abstract.

The purpose of this study was to determine the results of testing the development of chemical modules on thermochemical materials. The method used in this study is a mixed method, namely qualitative and quantitative methods.Twelve assertions about the module, including its substance, language, presentation, and graphics, were included in a questionnaire that was used to collect the data. In order to improve the module, respondents were given the opportunity to offer suggestions at the conclusion of the questionnaire. The research's trial portion was conducted in two stages, a minor test and a major test. Chemistry instructors and pupils from three state senior high schools served as the study's subjects. While 30 students and 5 teachers were present for the major trial, only 15 students and 3 teachers were present for the minor trial. The results of the quantitative analysis obtained an average minor test result of 73.91% in the good enough category for teachers and 74.72% for students in the good enough category. Major test results obtained an average of 82.5% in the very good category for teachers and 80.13% for students in the very good category. The qualitative method is based on the suggestions given by the teacher and students and obtained from the questionnaire. There were several suggestions for revisions obtained during these two stages, namely the need to add the amount of information about chemistry, add answers to questions in the module, add pictures or illustrations, correct some typing errors, and slightly enlarge the column of student answers in the module.

Keywords: *Thermochemistry Module, Guided Discovery, Critical Thinking and Science Process Skills*
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I. INTRODUCTION

Critical thinking skills and science process skills are needed for students to understand complex chemistry learning materials such as thermochemistry. Thermochemistry includes various concepts that are concrete, abstract, involve mathematical operations, and have interrelationships between concepts. The concrete concept of thermochemistry can be demonstrated by the phenomena of increasing air temperature around the occurrence of combustion events and decreasing temperatures accompanying the reaction of urea with water, where both events are classified as examples of exothermic and endothermic reactions, respectively. Abstract thermochemical concepts can be illustrated by concepts related to heat transfer accompanying a chemical reaction, where the heat transfer cannot be observed directly. In studying chemistry, students are required to think abstractly to be able to understand submicroscopic and symbolic aspects, so many students experience difficulties in studying chemistry (Kozma and Russell, 1997; Sirhan, 2007).Critical thinking is something that needs to be worked on in learning activities not just in Indonesia but also in other nations like the US as well as Iran (Malmir and Shoorcheh, 2012; Thompson, 2011). Almost all educators recognize the significance of cultivating students' critical thinking abilities in the proper manner (Malmir and Shoorcheh, 2012). To maximize students' critical thinking not only in the output but also in the learning process, instructors must innovate in the classroom. According to Halpern, one of the skills necessary for student success is critical thinking (Cain et al., 2012). Critical thinking can be developed through guided discovery learning, in which the teacher facilitates students' knowledge construction through investigation and active participation in the process (Van Hong et al., 2017).

Critical thinking teaches students to analyze problems using pertinent queries and data (Duron et al., 2006). The instructor submits questions or statements that direct students step-by-step toward achieving the predetermined goals or objectives (Van Hong et al., 2017). Guided discovery is a method that can guide and direct students to learn independently and discover their own knowledge (Ramdhani, et al, 2017; Ellizar et al., 2018). Concept discovery is based on a problem presented by the teacher in order to pique students' interest and enhance their problem-solving abilities (Aktamiş and Ergin, 2008; Khabibah et al., 2017). The preceding explanation demonstrates that the teacher is merely a facilitator in the learning process, whereas the pupils are the primary actors. (student-centred). According to Facione, aspects of critical thinking include interpretation, analysis, evaluation, inference, explication, and self-control (Ellizar et al., 2018) .Learning science does not only emphasise mastery of products but also mastery of process skills and scientific attitudes. Process skills in science learning are known as science process skills (Juhji, 2016). In learning chemistry, it is not only required to emphasise existing knowledge products but also how to obtain them because good products result from optimal mastery of process skills. Therefore, the process of discovering a concept should not be ignored in learning chemistry. Chemistry learning, which emphasises a process, can be realised through optimising students' skills as inventors, which are also called science process skills (Ergül, 2011) . Science process skills are skills in applying the scientific method to think and solve problems as a process of constructing concepts, including skills in discovery, experimentation, and drawing conclusions (Zimmerman, 2007).

Science process skills include aspects of observation, interpretation, classification, prediction, communicating, hypothesising, planning experiments, applying concepts, and asking questions. Developing science process skills in learning can increase scientific creativity and student learning outcomes (Rustaman et al., 2005). The right learning process is expected to be able to develop students' science process skills so that they can support students' strong mastery of concepts (Chabalengula et al., 2012).The syntax for guided discovery learning includes problem statements, stimulation, data collection, data processing, verification, and generalization (Aktamiş and Ergin, 2008). There is a correlation between guided discovery, critical thinking, and science process abilities, which enables guided discovery to train both. Based on the results of the interviews, the teacher implemented innovations into the guided discovery learning model, but the students were perplexed because they were not accustomed to it. The teacher said that the application of the guided discovery learning model would be easier if there was an appropriate guidebook to support the course of learning. This is the main reason for compiling modules that make it easy for students to learn. The results of the analysis of the teacher's needs for the preparation of the guided discovery module show that the textbooks used do not cover all the guided discovery learning syntax (Widura, et al., 2015). Learning using discovery-based learning modules can support students in discovering concepts from material (Kartika et al., 2017). Modules are not only used as a study guide, but also as a way to stimulate students' critical thinking and science process skills (Febriana et al., 2017) . The modules systematically contain materials designed to help students (Situmorang and Handayani, 2017) .Based on these needs, this research focuses on the preparation of thermochemical modules that are adapted to the guided discovery syntax. The compiled modules can not only be used in class but also during practicum in the laboratory. The module is developed with practicum activities so that students can understand the thermochemistry material. This module is used by students as a study guide so that learning becomes more systematic and effective.

II. METHODS

This study seeks to determine the outcomes of expert-validated learning module trials. This research employs descriptive qualitative and quantitative methods. A qualitative method founded on teacher and student recommendations, The collection of quantitative data is founded on the scores obtained from respondents. Module evaluations were conducted in two phases, including minor and major tests. The subjects in this study were chemistry teachers and students of class XII grade science in three high schools with high, medium, and low categories. This research was conducted in the city of Surakarta, Indonesia. 15 students and 3 teachers participated in minor trials, while 30 students and 5 teachers participated in major trials. In the questionnaire given, teachers and students are allowed to write down their suggestions for improving the learning module, which will then be revised according to the suggestions obtained so that the module becomes better. The score obtained from the respondents is calculated using this formula:

$$P = \frac{n}{N} \, x \, 100\%$$

P: percentage score (%), n: the number of scores obtained, N: the maximum number of scores. If the P value is ≥ 75%, the developed module product set is suitable for use in the learning process. The scoring criteria for the module are as follows: 0–25% indicates the category is not good, 25.1–50% indicates the category is quite good, 50.1–75% indicates the category is good, and 75.1–100% indicates the category is very good.The module is verified by professionals prior to testing. The evaluation components, which were taken from the 2014 BSNP Textbook evaluation Instrument, are content eligibility, presentation feasibility, language eligibility, and graphic feasibility. The validator gives an assessment in the form of a 1-4 score scale: 1 score scale for poor assessment, 2 score scale for fair assessment good, 3 score scale for good assessment, and 4 score scale for very good assessment (Sugiyono, 2012). Then the score is calculated to determine the validity of the score using the Aiken formula (Aiken, 1980) . If the validation number is greater than 0.78, the module is deemed to be valid. This is Aiken's equation:

$$V = \frac{s}{[n \, x \, (c-1)]}, \quad S = \sum ni(r\text{-}lo)$$

V : validity index from Aiken, ni : the number of raters who choose the criteria, c : the amount of categories and criteria, r : criterion to I, lo : lowest category, n : total number of evaluators,

III. RESULTS AND DISCUSSION

Development

The preliminary stage, the development stage, the product revision stage, and the product trial stage comprise the module development stage. The preliminary phase is used to identify the problem and a viable solution. After making observations, conducting interviews, and submitting questionnaires to teachers and students, it is necessary to prepare modules. Then, a literature review was conducted on the theoretical concepts associated with the module, focusing on the correlation matrix between guided discovery, critical thinking, and scientific process skills. The development phase is tailored to the curriculum and syllabus of thermochemistry. This phase determines the module's structure, and the module's content is tailored to guided discovery syntax, aspects or indicators of critical thinking, and science process skills. Then, module validation is carried out by material experts, media experts, learning experts, linguists, and educational practitioners so that the module is feasible and valid to be tested on teachers and students. If feedback is received, the module can be revised. On the basis of the matrix between guided discovery, indicators of critical thinking, and indicators of science process skills, the characteristics of the developed module are modified. In the stimulation phase, students will be given thermochemical phenomena that occur in everyday life (Van Hong et al., 2017). At the stage of the problem statement, students must identify the problem and make a hypothesis based on the given phenomenon. Students design practicums to prove the hypotheses they have made.This practicum is carried out by students in groups so that they can work together to solve problems. By doing it in groups, it is able to stimulate students and produce more intense thinking about a problem (Achera et al., 2015). At the data collection stage, students must acquire practicum data and other pertinent information. Students are required to record their practicum data in the column provided. Students will process data from practicum results during the data processing phase.

This step must be taken to acquire new knowledge so that students can learn to independently locate concepts. Groups of students process data in order to enhance each student's communication skills (Makoolati et al., 2015). At the verification stage, students examine the concepts they find to determine whether they are in accordance with the hypotheses made at the beginning of learning or not. In other words, during the verification stage, students evaluate the previously learned concepts. It is also a systematic process that trains students' critical thinking skills and science process skills (Makoolati et al., 2015). At the generalisation stage, students will draw conclusions from the concepts they found during the practicum. After doing the practicum, students need to associate the concepts they learned during the practicum with the phenomena given at the stimulation stage.To maximize students' critical thinking and science process skills, the developed module is comprised of numerous questions that guide students to discover the concepts being taught. According to experts or validators, it is necessary to increase the quantity of chemistry-related information, add answers to queries in the module, include images or illustrations, correct some typographical errors, and slightly enlarge the student response columns in the module. Based on calculations using the Aiken formula, Table 1 presents the following validation outcomes.

Table 1. Results of Aiken Validation Calculations on the Module

Aspects	Aiken Validity Index	Description
Content	0,88	Valid
Presentation	0,88	Valid
Language	0,86	Valid
Graphical	0.88	Valid
Average	0,87	Valid

Based on calculations, all aspects are declared valid because they have an Aiken validity value of more than 0.78.Table 2 presents the validation results for the indicators of the modules on critical thinking and science process skills. The calculated value of the Aiken validation index is greater than 0.78, indicating that the guided discovery steps in the module are clear and capable of directing students to maximize each indicator of critical thinking and science process skills, as shown in Table 2.

Table 2. The results of the validity of critical thinking, guided discovery, and science process skills in the module

Phase of Guided Discovery	Aiken Validity Index	Indicator of CriticalThinking	Aiken Validity Index	Science Process Skills Indicators	Aiken Validity Index
Stimulation	0,86	Interpretation	0,88	Observing	0,86
Identification	0,87	Analysis	0,87	Making a hypothesis	0,87
Data collection	0,88	Evaluation	0,88	Planning an Experiment	0,88
Data processing	0,87	Inference	0,89	Classify	0,87
Verification	0.88	Explanation	0.84	Applying concepts	0.88
Generalization	0,85			Communicating	0,85
Average	0.87		0.87		0.87

Module test

The objective of this test is to collect information about the product, namely the module, to guarantee its quality and efficacy. There are 12 questions classified into 4 aspects, which consist of the content aspect, language aspect, presentation aspect, and graphic aspect. This aspect of the assessment is adjusted to the 2014 BSNP textbook assessment. Assessment on the content aspect relates to the clarity of the material presented in the module, the attractiveness of the content and material presented in the module, and the ease of the material presented in the module. Clarity in the use of language to explain the material in the module, visual writing in the module, and clarity in the use of language to explain learning material are examples of language-related statements.The presentation aspect statement is the clarity of the guided discovery stage in the module, the ability of the module as a learning resource, and the ability of the module to foster critical thinking skills and science process skills. Statements about the graphical elements of the module, such as the color schemes used, the module layout that makes the content fascinating to study, and the degree to which the pictures and illustrations in the module are interesting in order to make the learning material interesting. Based on the results of the assessment of the results of the minor and major trials conducted by the teacher, the results of the assessment are obtained, as shown in Figure 1 below.

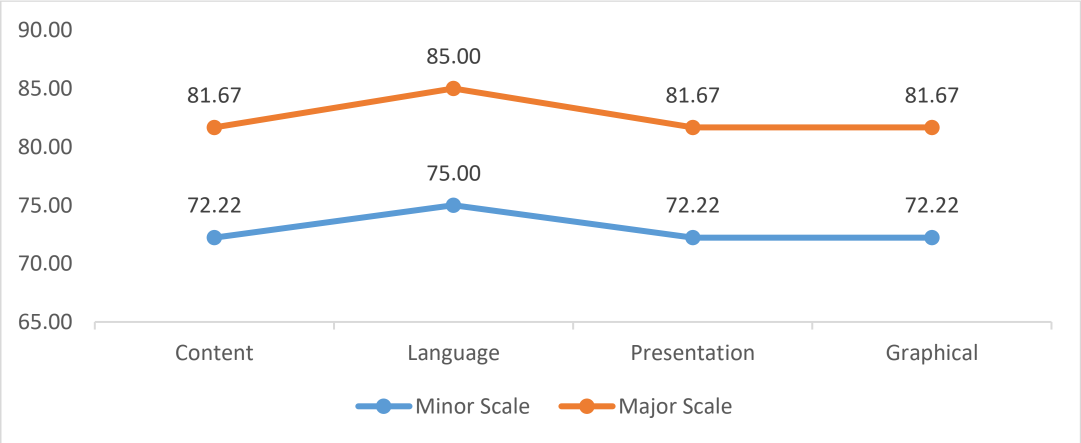

Fig 1. Module trial results by teacher.

Based on Figure 1, it can be seen that in the minor trial, the teacher gave an assessment in the "good" category. Based on the results of the minor scale trial, suggestions for improvement were obtained from the teacher. After revision, a major trial was carried out. The teacher gave an assessment in the "very good" category for the module on the major scale trial.Figure 2 below displays the outcomes of students' minor and major trials.

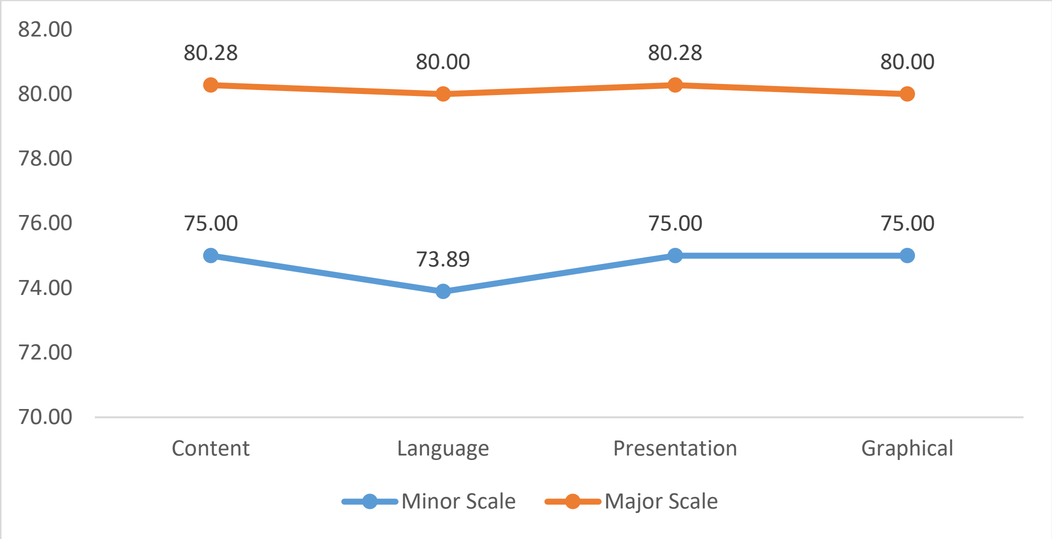

Fig 2. The results of the module trial by students

Based on Figure 2, the results of the module trial assessment show the student's response to the module being developed. In the minor trial, students give an assessment in the "good" category for the module. After revision, the module was re-tested and received an assessment in the "very good" category.

IV. CONCLUSION

According to the results of the validation and trials conducted, the developed modules can assist students in enhancing their critical thinking and science process skills. The developed module conforms to the 2014 BSNP textbook evaluation. The module can encourage students to study thermochemistry using critical thinking and scientific process skills. The guided discovery-based characteristics of the module are supplemented by queries that teach students to solve problems systematically. Teachers and students have responded positively to the results of module development, as demonstrated by the module trial results.

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