Chemistry module based on guided discovery to improve critical thinking ability: development and trial results

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Abstract. The aim of this research is to know the results of trials on chemical modules on thermochemistry chapter developed. The method used in this research is mixed method those are qualitative and quantitative method. Techniques used by giving a questionnaire with 12 statements include content, language, presentation, and graphics. In the end of questionnaire, the respondent allowed to write his/her suggestion to improve the better module. The trials are conducted in two stages: minor and major test. The test subjects were chemistry teachers and students in three public senior high school. Minor trial used 15 students and 3 teachers, while major trials have 30 students and 5 teachers. Quantitative method obtained results of minor test calculations 73.3% with quite category for students and 73.6% for teachers with quite category, major test results obtained 80% with good category for students and 81.6% for teachers with good category. Qualitative methods based on advice provided by teachers and students. There were revisions that obtain during these two stages those are the changing of cover’s colour and improving the icon in module.

1. Introduction

Critical thinking is needed for students in order to comprehend complex material like thermochemistry. It is one of the complex subjects because it is related with chemical reaction, stoichiometry, and chemical bonding. Besides, thermochemistry consists of abstract concept and mathematical equation. These interrelated concepts make it difficult for students to learn thermochemistry. Thermochemistry is one of the material encouraging students to think critically, where it has abstract concept but its applications are found in the daily life [1]. Students’ difficulties in thermochemistry are distinguish between system and environment, understand the exothermic and endothermic reactions, determine the type of reaction based on a case, and error in enthalpy changes calculation [2]. Most of the time, students learn by memorizing not by understanding the concept. Learning by memorizing causes students to easily forget and they are not be able to understand the intact materials. By interviewing teachers in three different schools, students’ scores in thermochemistry are low. There are only a few students get above the minimum completeness. This way of learning should be changed, if this goes on, it will affect their concept mastery and outcomes.

Based on the current curriculum used in Indonesia (curriculum 2013), critical thinking is one of the aspect that need to be developed. Not only in Indonesia, but critical thinking ability also applied in other
countries such as, America, and Iran [3,4,5]. Almost all teachers realize the important of developing students’ critical thinking ability with the correct way [3] Teachers need to innovate in learning process to maximize the students’ critical thinking not only from the output, but also in the learning process. The philosophy of critical thinking competence needs to shift from the output into process, learning becomes thinking process, and closed to a subject into integrated subject [4]. According to Halpern, critical thinking is one of the ability needed in order to students for succeed [5]. Critical thinking can be developed through guided discovery learning, teacher facilitates students to build knowledge by investigating or research and participate actively in the construction process of students’ knowledge [6]. Critical thinking trains students to analyze problems based on questions and relevant information [7]. Teacher delivers questions or statements that lead students step by step to get to the objectives or predetermined target [6]. Guided discovery is a method that able to guide and direct students to learn individually and find their own knowledge [8,9]. Concept finding is based on a problem given by the teacher, so it will trigger students’ curiosity and improve their performance to solve problems well [10,11]. Those explanations above showed that teacher is only a facilitator in a learning process, while students are the main doer (student-centered).

Critical thinking aspects according to Facione are interpretation, analysis, evaluation, inference, explanation, and self-regulation [9]. Syntax of guided discovery learning consists of problem statement, stimulation, data collection, data processing, verification, and generalization [10]. Guided discovery is able to train critical thinking ability because there is correlation between them. The results of the research showed that in stimulation stage can train explanation, problem statement stage trains interpretation, data collection stage trains interpretation, analysis, and explanation, data processing stage trains analysis and explanation, verification stage trains explanation, generalization stage trains evaluation, explanation, and self-regulation [11]. There are differences in critical thinking indicators at each stage of guided discovery, and the most frequently trained indicator is explanation.

Based on the interview, teacher had made learning innovation using guided discovery learning model, but students confused because they are not used to it. Teacher said the implementation of guided discovery will be easier if there is a suitable guide book. This can be the main reason to compose module which facilitate students to learn. Analysis results of teacher’s need of module composing in guided discovery are the students’ books have not covered all learning syntaxes of guided discovery and there are books which indirectly addressed the indicator [12]. Learning by using a discovery-based learning module supports students to discover concept from the materials [13]. Not only as a learning guide, but module is also used as a solution to stimulate students’ critical thinking [14]. Module systematically contains materials designed to help students [15]. Module structure consists of introduction, students’ activity, teaching guidance, assessment, and teacher’s notes.

Previously, there are some relevant researches conducted such as the effectiveness of discovery-based module on acid base materials [16], and the effectiveness of skill-based module of critical thinking on thermochemistry for college students, worksheet composing to improve critical thinking ability on thermochemistry [17], and preparation of laboratory worksheet student base on guided inquiry to improve students’ learning results on thermochemistry [18]. Those researches showed the module effectiveness to improve critical thinking ability and the use of guided discovery-based module. Those researches emphasize in making learning guidance on thermochemistry. Guided discovery-based module development has done on acid base materials, while for thermochemistry module focuses on college students. In the other hand, thermochemistry worksheet development had ever done but it was not guided discovery-based and only focus on lab work activities. Based on the need, this research focuses on composing thermochemistry module to be adjusted with guided discovery syntax. This module not only can be used in the classroom, but also in the laboratory. It packs up with lab work activities so the students are able to comprehend thermochemistry materials. This module is used as a guidance by students so the learning will be more effective and systematic.
2. Method

This research has purpose to find out the module trial validated by experts. The methods used in this research is descriptive qualitative and quantitative. The qualitative methods based on advices provided by teachers and students. The quantitative data collecting are based on the respondents’ score. The trials are conducted in two stages: minor and major test. The subjects of this research were chemistry teachers and XII grade science students in three senior high school with high, intermediate, and low category. The research conducted in Pontianak, West Borneo. Minor trial used 15 students and 3 teachers, while major trials have 30 students and 5 teachers. In the end of questionnaire, the respondent allowed to write his/her suggestion to improve the module better. Score of respondents are calculated to find out the response using this formula:

\[ P = \frac{\sum x}{\sum n} \times 100 \]  

(1)

P = percentage, \( \sum x \) = number of obtained score, and \( \sum n \) = number of maximum score that can be obtained [19]. The data collected showed some responses of module, for 0-25% showed low responses, 25, 1-50% showed average responses, 50, 1-75% showed good responses, 75, 1-100% showed very good responses. Before trial test, module is validated by experts. The assessment aspects consist of content eligibility, presentation eligibility, linguistic eligibility, and graphical eligibility which is adapted from Text Book Appraisal Instrument BSNP 2014. The validator gave assessment in the form of scores (scores 1-4). Then, the scores are calculated to find out the validity scores using Aiken formula. Module is valid if the validation value is more than .78. Here is Aiken's formula:

\[ V = \frac{S}{n \times (c-1)} \times \sum ni(r - lo) \]  

(2)

V = Aiken validity index, \( n_i \) = the amount of scorer choose i criteria, \( c \) = amount of categories/criteria, \( r \) = criteria to I, \( lo \) = lowest category, \( n \) = total of scorer [20].

3. Result and discussion

3.1. Development

Module development stages started with introduction stage, development stage, product revision stage, and product trials stage. Introduction stage is done to find out the problem and the good solutions. After did an observing, interviewing, and delivering the questionnaires to the teacher and students, module composing is necessary. Then, study literature is conducted on theoretical concept associated with the module, especially correlation matrix between guided discovery and critical thinking. Development stage is adjusted with curriculum 2013 and thermochemistry syllabus. This stage determines the module design, module content adjusted with guided discovery syntax and critical thinking aspects/indicators. Then, validation is done by material experts, media experts, teaching experts, linguistic experts, and education practitioner. The proper and valid module is tested on teacher and students. If there are some suggestions, the module will be revised.

The module characteristics which is developed is adjusted based on matrix between guided discovery and critical thinking indicator. Stimulation stage, students are given thermochemistry phenomenon in daily life about wood burning and ice cream melting. Stimulation question like “is there any energy transfer?”, “In the event of burned woods, the body feels the heat from the fire resulting in the transfer of energy from… to …”, “The event indicates that the heat release is …. while the one receiving the heat is …”, and other questions related to exothermic and endothermic reactions, and enthalpy. Students are given some questions to guide them so they focus on what they are studying [6]. Problem statement stage, students have to identify the problems and make hypothesis about exothermic and endothermic reactions. Siswa merancang praktikum to prove the hypotheses. This lab work is done in a group so they are able to cooperate to solve the problems. De leon said that group work is able to stimulate students...
and generate more intense thinking of a problem [21]. Data Collection stage, students have to collect data earned in the lab work and gather the relevant information. The student must write the data about exothermic and endothermic reactions into the provided column. There are some sample questions such as, “What is the temperature of the compound before and after being extracted? “What does it feel when the glass is touched by hand?” “which one is the system and the environment?” Data processing stage, students process the lab work data result. This step needs to be done to earn new knowledge so that the students learn to find the concept individually. Data processing is done in group to improve interpersonal skills of each students in communicating [22]. There are some sample questions such as, “exothermic reaction is a reaction that … heat energy, while endothermic reaction is a reaction which … heat energy”, and questions that lead students to draw reaction diagram from the compound used by the students. Verification stage, students do examination on the concept they found whether it is in line with the hypothesis or not. In other words, verification is students’ way of evaluating exothermic and endothermic concept they found. It is also a systematic process that train students’ critical thinking [23]. Generalization stage, students make a conclusion from the concept they found earlier. After doing the lab work, students need to associated exothermic and endothermic concept with the given phenomenon on stimulation stage. Students have to be able to determine the type of reaction on a burned wood.

To maximize the students’ critical thinking, the developed module consist of many questions that point the students to find the concept of what the study about. In the beginning stage, students directly involved in the explanation stage in finding the concept. Interpretation is trained when students formulate the problems and designing the research to prove the hypothesis. Students do the analysis when processing data because they need to formulate the hypothesis. Inference and evaluation are done by students when they make conclusion based on the facts found. On the other hand, module consist of examples, exercise, and answer key, illustration/pictures, glossaries, and material. Some suggestions from the experts or validators are increase the number of information about chemistry, add answers from the questions, pictures or illustrations, increase the title size, and change cover of module. Based on the calculation using Aiken formula, here are the following validation results presented in table 1.

| Aspects     | Average Value V | Description |
|-------------|-----------------|-------------|
| Content     | .873            | Valid       |
| Presentation| .883            | Valid       |
| Language    | .849            | Valid       |
| Graphical   | .895            | Valid       |
| Average     | .875            | Valid       |

Based on the calculation, the highest aspect is graphical appropriateness, because there are illustrations/pictures and compatible and matching colour inside the module design. For the result of critical thinking indicator validation of the module presented in table 2. Based on table 2, it showed that the guided discovery steps within the module are clear and able to lead students to maximize every critical thinking indicator.

| Stage of Guided Discovery | Average Value V | Description | Indicator of Critical Thinking | Average Value V | Description |
|---------------------------|-----------------|-------------|--------------------------------|-----------------|-------------|
| Stimulation               | 0.861           | Valid       | Interpretation                 | 0.916           | Valid       |
| Identification            | 0.833           | Valid       | Analysis                       | 0.833           | Valid       |
| Data collection           | 0.861           | Valid       | Evaluation                     | 0.888           | Valid       |
3.2. Module trials

The purpose of these trials is to collect the data related to the product, which is the module, so there will be a good quality and effectiveness. There are 12 questions classified into 4 aspects, that is content, language, presentation, and graphical aspects. Those statements are adjusted with Text Book Assessment BSNP 2014. Statements of content aspects are materials clarity presented in the module, content and materials visual presented in the module, and materials easiness presented in the module. Statements of language aspects are written use clarity in describing the material, writing visuals in the module, and language use clarity in describing the materials. Statements of presentation aspects are guided discovery stage clarity in the module, module capability as learning resources, and critical thinking clarity in the module. Statements of graphical aspects are color combination in the module, module design makes the material is pleasing to study, and pictures/illustrations attractiveness in the module. Based on the calculations, here are the results of minor and major trials by teacher as in following figure 1.

Based on figure 1, showed the teacher’s response on minor trials gave “good” response. On major trials teacher gave “very good” responses to the module. The highest response is on graphical aspects. The minor and major trials results by students presented in the following figure 2. Based on figure 2, trials presentation showed the students’ response on the developed module. On the minor trials, students’ gave “good” response to the module. After revision, module is re-tested and earned “very good” response.

| Table 2. Cont.                  | Data processing | 0.861 | Valid | Inference | 0.888 | Valid |
|---------------------------------|-----------------|-------|-------|-----------|-------|-------|
| Verification                    | 0.888           | Valid | Explanation | 0.944 | Valid |
| Generalization                  | 0.916           | Valid |             |         |       |
| Average                         | 0.870           | Valid |             | 0.893  | Valid |

Figure 1. Module trial result by teacher.

Figure 2. Module trial result by students.
4. Conclusion

Overall validation results and module trials showed the developed module can help students improve critical thinking skills. The module is appropriate according to Text Book Assessment BSNP 2014. It can motivate students to use their thinking ability by posing questions related to thermochemistry. The characteristics of the developed modules are complemented by questions that lead students to systematically construct the concept within themselves. It showed from the module trial test results, teacher and students showed positive responses to the modules.

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