Development of problem-based learning module on electrolyte and nonelectrolyte solution to improve critical thinking ability

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Abstract. Problem Based Learning (PBL) is one of the instructional models suggested in 2013 curriculum and can be applied in the development of module so that students become active in the learning process and improve critical thinking ability. This study is aimed to develop and determine the level of validity and practicality of PBL module on electrolyte and nonelectrolyte solution to improve critical thinking ability. It adopts Plomp development model and did in two schools namely SMA N 1 Sijunjung and SMA N 7 Sijunjung. The research instrument used in form of questionnaires and analyzed by kappa cohen formula. The result showed that the developed module has a very high category of validity and practicality. Thus, the developed module contains correct information scientifically and easy to use by students and teachers in learning. The PBL steps in the module lead the students to discover the concept independently and train their critical thinking ability.

1. Introduction

Science is one of the tools to develop critical thinking ability. Critical thinking is an important and vital topic in modern education era. A person who thinks critically capable of asking the right questions, gathering relevant information, acting efficiently and creatively based on information, can put forward a logical argument and can make conclusions [1]. One that is studied within the scope of science is chemistry. Chemistry is considered to be a difficult subject for the students because it consists of many abstract concepts or theories [2].

Chemical learning in the 2013 curriculum (curriculum in Indonesia) refers to a scientific approach. The application of the scientific approach in the learning process can be supported by the use of learning model, one of them is PBL model. The PBL model is a learning model with a student learning approach to authentic problems so that students can develop their own knowledge, develop higher skills and inquiry, establish students and improve self-confidence [3]. By providing problems in a learning, students’ critical thinking ability will be trained to analyze and solve the problems.

PBL is an effective strategy or method with use of real-world problems so students learn to think critically and improve problem-solving skills to assimilate important concepts across multiple disciplines. PBL can involve individual and group activities, stimulate curiosity, intrinsic motivation, self-study as well as personal and group reflection [4]. Research by Draghicescu [5] shows that PBL is a suitable strategy for science learning (Chemistry, Physics, Biology) because of this model based on student-centered learning. Students taught by PBL models have a higher value [2]. In addition, research by Kek [6] also states that PBL is a teaching and learning system that harmonizes to teach critical thinking ability in various disciplines.
Application of learning model can be supported by using the suitable teaching materials. The suitable teaching materials can support the achievement of learning objectives by attracting interest, stimulating and motivating students to be active in the learning process. One example of teaching materials is a module. A module is a complete unit consisting of a series of learning activities designed to help students achieve the learning objectives effectively and efficiently and provide opportunities for students to learn in their own way [7]. Ellizar's study [8] suggests that students' learning outcomes using modules on atomic structure materials, reaction rates and thermochemistry are better than those without modules. By learning to use colorful and pictorial modules, students become interested in teaching materials so as to enhance motivation in learning.

Electrolyte and nonelectrolyte solution is one of the chemistry subject material taught in grade X senior high school. This material contains factual, conceptual and procedural knowledge. To understand the electrolyte and nonelectrolytes solutions material well, students should be trained to find concepts independently and carry out experiment activities as learning experiences for students. In facilitating it, it takes a teaching materials in the form of modules that can be used by students to learn independently or in the classroom learning. PBL model can be applied in the development of modules for this material. This is because development of PBL module presents problems in the early stages of learning that are equipped with a chemical representation model, containing student activity sheets in the discussion, and practicum as investigation activities. PBL model is suitable for studying the material of electrolyte and nonelectrolyte solution because the application of this material is very close to the problems of everyday life. The PBL module containing the concept discovery with daily life-giving problems to students and experiment activities that refer to the steps of the scientific method can train and improve students’ critical thinking ability.

Based on observations and interviews with several chemistry teachers and students of three senior high schools in Sijunjung district, West Sumatra, Indonesia obtained information that some students still difficult to understand the electrolyte and nonelectrolyte solution material. Generally, this material is taught with the experimental method and group discussions use textbooks and student worksheet. Some students and teachers mentioned that the explanation of the material and examples of the question presented in the textbook is too long so that students difficult to find the main concept. Some concepts are still given directly in the textbook, so the process of self-discovery of concept by the students has not been done completely. While in the 2013 curriculum, students are required to be able to find the concept independently. In addition, the student worksheet used are not colored so as to be less interesting for students to learn.

Based on the test of students’ critical thinking ability that has been done during preliminary research by using essay questions, it can be concluded that the overall of students critical thinking ability still needs to be trained and improved. The data obtained are as follows.

| No. | Indicator of Critical Thinking Ability by Ennis | % Student Ability |
|-----|--------------------------------------------|------------------|
| 1   | Elementary Clarification                   | 55.56%           |
| 2   | Basic Support                              | 55.56%           |
| 3   | Inference                                  | 86.67%           |
| 4   | Advanced Clarification                     | 57.78%           |
| 5   | Strategy and tactics                       | 60%              |

Seeing the conditions that occur in the field, need to develop teaching materials that can improve the deficiencies that still exist in teaching materials that have been used in schools. One of the teaching materials that can be developed is PBL module on electrolyte and nonelectrolyte solution to improve students’ critical thinking ability. By using a PBL module, students are expected to be able to learn independently and find the concept of the subject matter through the analysis of problems given at the beginning of the learning so that students' critical thinking ability can be trained and improved.
2. Methods
The type of research conducted is Research and Development (R & D). The product developed in the form of PBL module on electrolyte and nonelectrolyte solution to improve critical thinking ability of high school students by using Plomp model. This development model consists of three stages, namely preliminary research, development or prototyping phase, and assessment phase [9].

In preliminary research stage, problem and need analysis do to collect information about problems occurring in the learning process of chemistry in schools, especially on electrolyte and nonelectrolyte solutions material. Information gathering was conducted through interviews with several chemistry teachers and high school students in Sijunjung District. Information about students' critical thinking ability is obtained through critical thinking ability tests conducted using essay questions that refer to the critical thinking indicator according to Ennis. In addition, curriculum analysis is also conducted to formulate indicators of achievement of competencies and learning objectives to be achieved by students. Analysis of student concepts and analysis is also done at this preliminary research stage. The concept analysis aims to identify, detail and systematically arrange the necessary concepts and be used as a reference in the development of PBL module, while student analysis is done to know the character of students who become the target users of a developed product.

At the development or prototyping phase, a PBL module is designed for electrolyte and nonelectrolyte solution materials to improve critical thinking ability of high school grade X students. The module's initial design is called prototype I. The components in the module include the cover, introduction, table of contents, images list, module usage instructions, competencies (core competencies, basic competencies, indicators, and learning objectives), concept maps, activity sheets, worksheets, key answers, and references. Development of modules tailored to the PBL learning model stages, namely student orientation to the problem, organize students to learn, guide individual and group investigations, develop and present the work, analyze and evaluate the problem-solving process. The completed module is designed then conducted self-evaluation by using a checklist. Self-evaluation is done to check for errors or flaws that may still be found in the module. The module is then revised to produce prototype II.

Prototype II then validated by experts using the instrument in the form of module validation sheet covering aspects of content, construct, language and graphics. Validator suggestions are used for module revision. After the module was revised, the module was given to 3 students to do one to one evaluation aimed at knowing the legibility of developed module. The instrument used in the form of interview guides. The revised module at this stage is called a prototype III.

Prototype III was given to 6 students to do small group/micro evaluation, where students were taught using modules during one meeting. After the learning process, students are asked to fill out the module practice questionnaire. Suggestions from students are taken as input for module revision. The result of revision at this stage is called prototype IV which will then be tested in a large group (field test) in the assessment phase.

Assessment phase aims to see how far the practicality and effectiveness of modules developed. However, in this study, the assessment phase is limited only to see practicality module based on teacher response and student response in two schools in Sijunjung District. The module practice is based on a questionnaire filled by teachers and students. The results of validity and practicality test are analyzed using kappa cohen formula to generate kappa moment. The decision categories based on the kappa moment [10] can be seen in Table 2.

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Table 2: Decision Categories Based on Kappa Moment
Table 2. The decision categories based on the kappa moment.

| Interval      | Category |
|---------------|----------|
| 0.81 to 1.00  | Very high|
| 0.61 to 0.80  | High     |
| 0.41 to 0.60  | Medium   |
| 0.21 to 0.40  | Low      |
| 0.00 to 0.20  | Very low |
| < 0.00        | Invalid  |

3. Results and Discussion

3.1. Results

First stage of development in this study is preliminary research activity aims to find out the problems experienced by students in school about learning chemistry. The results obtained on preliminary research are as follows. Some students still difficult to understand the electrolyte and nonelectrolyte solutions material. Generally, this material is taught with the experimental method and group discussions use textbooks provided by schools and student worksheet. Some students and teachers mentioned that the explanation of the material and examples of questions presented in the textbook is too long so that students difficult to find the main concept. Some concepts are still given directly in the textbook, so the process of self-discovery of the concept by the students has not been done completely. While in the 2013 curriculum, students are required to be able to find the concept independently. In addition, the student worksheet used are not colored so as to be less interesting for students to learn. The result of critical thinking ability test in three schools shows that overall students' critical thinking ability still needs to be trained and improved.

The second stage is development or prototyping phase. In this stage, 4 prototypes are produced. The prototype 1 is the initial design of PBL modules on electrolyte and nonelectrolyte solution materials prepared according to the syntax of PBL model to improve students' critical thinking ability. The design of the module is based on preliminary research results that have been done. The creation of this module uses Microsoft Word 2007 applications, with Times New Roman writing sizes 12, 14 and 18. The components in this PBL module are cover, introduction, table of contents, image list, module usage instructions, competencies (core competencies, basic competencies, indicators, and learning objectives), concept maps, activity sheets, worksheets, answer keys and references.

Stages of the PBL model are applied to module activity sheets, ie student orientation to problems, organizing students for learning, guiding individual and group investigations, developing and presenting work, analyzing and evaluating problem-solving processes. Through the stages of this PBL model, students are trained to enhance critical thinking ability such as analyzing problems, formulating hypotheses, gathering relevant information, raising logical arguments and drawing conclusions. The module comes with an answer key so students can correct the answers they have made and as a clarification if there is a wrong concept of the students.

Module that have been designed and then performed self-evaluation by using a checklist. Self-evaluation is done to check for errors or deficiencies that are still found in the module and whether all the important components are loaded inside the module such as module components and PBL model steps to improve students' critical thinking ability. The module was then revised and produced a prototype II.

Prototype II was further validated by 7 experts (5 chemistry lecturers and 2 high school chemistry teachers). Aspects assessed include component of content, constructs, language, and graphics. The results of validation by experts analyzed using kappa cohen can be seen in Table 3.

Based on Table 3 can be seen the validity of the module as overall is 0.90 with a very high category of validity. These results indicate that the PBL module developed has been valid in terms of content, constructs, language, and graphics so that it can be used for one to one evaluation.
Table 3. The results of module validation by experts.

| Aspects Assessed       | Kappa moment | Validity Category |
|------------------------|--------------|-------------------|
| Content Component      | 0.89         | Very high         |
| Construct Component    | 0.86         | Very high         |
| Language Component     | 0.95         | Very high         |
| Graphics Components    | 0.89         | Very high         |
| Average                | 0.90         | Very high         |

Based on the results of interviews with 3 students at one to one evaluation stage, from the clarity aspect it was found that the instruction of module usage, the presentation of the material, the language and the learning steps in the module are presented clearly and easily understood by the students. In terms of appeal, students express interest and like the look, image, and color used in the module. Students also stated that they did not find any writing errors and punctuation (obvious errors) on the module.

The next stage is small group/micro evaluation conducted on 6 students. Students learn to use modules developed during a meeting and then asked to fill out the module practical questionnaire. The result of module practicality based on student response at small group stage can be seen in Table 4.

Table 4. Category of practicality module based on student response (small group).

| No | Aspects Assessed            | Kappa moment | Practicality Category |
|----|------------------------------|--------------|-----------------------|
| 1  | Ease of use                 | 0.94         | Very high             |
| 2  | Efficiency of learning time | 0.91         | Very high             |
| 3  | Benefits and appeal         | 0.92         | Very high             |
|    | Average                     | 0.92         | Very high             |

Based on Table 4, the module practicality value of the small group evaluation activity overall is 0.92 with a very high category of practicality.

The last stage is assessment phase. This stage aims to see the practicality of modules in a large group (field test). Assessment phase is done in two schools namely SMA N 1 Sijunjung and SMA N 7 Sijunjung. Practical module data is obtained from a questionnaire of practicality filled by teachers and students who have learned to use modules developed during 2 meetings. The result of module practicality based on teacher response can be seen in Table 5.

Table 5. Category of practicality module based on teacher response.

| No | Aspects Assessed                                      | Kappa moment | Practicality Category |
|----|-------------------------------------------------------|--------------|-----------------------|
| 1  | Ease of use                                           | 1            | Very high             |
| 2  | Efficiency of learning time                           | 1            | Very high             |
| 3  | The attractiveness of teaching materials to student interests | 0.90         | Very high             |
| 4  | Benefits                                              | 1            | Very high             |
|    | Average                                               | 0.97         | Very high             |

Table 5 shows that the developed module has a very high category of practicality, meaning that the module is practically used in the learning process by the teacher. Level of module practicality based on student response (33 students of SMA N 1 Sijunjung and 30 students of SMA N 7 Sijunjung) can be seen in Table 6.
Table 6. Category of practicality module based on student response (field test).

| No. | Aspects Assessed               | Kappa moment | Practicality Category |
|-----|-------------------------------|--------------|-----------------------|
| 1   | Ease of use                   | 0.91         | Very high             |
| 2   | Efficiency of learning time   | 0.90         | Very high             |
| 3   | Benefits and appeal           | 0.88         | Very high             |
|     | Average                       | 0.89         | Very high             |

Based on Table 6, it can be concluded that developed module is practically used in the learning process of Chemistry on the material of electrolyte and nonelectrolyte solutions.

3.2. Discussion

3.2.1. Module Validity.

Etymologically, validity comes from the word "valid" which means right, true [11]. The product is valid if it contains accurate information [12]. Testing the validity of at least done by three experts [13]. The module developed was validated by 7 validators (5 chemistry lecturers and 2 high school chemistry teachers). Aspects consider determining the validity of the module include in terms of content, constructs, linguistics, and graphics.

Based on table 2, the module validity for all four aspects belongs to the very high category with the value of kappa moment 0.90. Judging from the aspect of the content, the modules developed must be in accordance with the core competencies, basic competencies, indicators and learning objectives to be achieved. In addition, the truth of the concept must also be considered both in terms of images (macroscopic and submicroscopic), the writing of chemical symbols and information contained in the module must be scientifically correct. Content validity is concerned with the process of finding the correct concept and in accordance with the applicable curriculum [14]. Products are said to be valid in terms of content if they meet their needs and components based on advanced scientific knowledge [9]. Based on validation result, kappa moment value for content aspect is 0.89 with very high category of validity. That is, the material presented in the module is correct according to the scientific rules and in accordance with the 2013 curriculum.

The module validity developed in terms of constructs also includes the very high category with the value of kappa moment 0.86. The assessment of this construct component is done by observing the systematics of module preparation that is adapted to the components of the module compiler and the steps of PBL model. Format / construct validity with respect to the suitability of module components developed with predetermined elements [14]. In addition, the order of presentation of the material is also arranged based on the learning objectives so that there are interrelationships between the concepts studied. The product is said to be valid in terms of collapse when all components are consistently interconnected [9]. Content validity indicates products developed in accordance with the curriculum (core competencies, basic competencies, indicators and learning objectives) and in terms of construct components in developed products are related to each other.

In terms of linguistic aspects, module validity is also categorized very high with the value of kappa moment (0.95). Indicators assessed by the validator in terms of linguistic include readability, clarity of information, the correctness of writing the correct Indonesian language and the utilization of language effectively and efficiently [15]. These results indicate that the language used in the module is easy to understand, the writing and the images can be read clearly and the writing of the sentence is in accordance with the rules of the correct Indonesian grammar.

Module validity from the aspect of graphics is very high with the value of kappa moment (0.89). Indicators to be considered from this aspect of graphics include layout and color of drawings, illustrations or photographs and product designs developed [15]. The result of module validity developed shows that the layout of drawings, colors, and designs used in the module interesting. The presence of images and visual symbols in the module can help students understand the concepts.
learned [16]. The use of color is a good way to store information in the brain because color can stimulate information related to the material learned [17].

3.2.2. Module Practicality.

The practicality of the module is related to the application of module developed in the learning process. The product is said to be practical if the teacher or student (representative of user target group) can easily use the product as expected [9]. Practice shows the level of ease of use and implementation of learning by using the resulting product. Teaching materials are said to be practical if they can be used to implement logical and continuous learning, without much problem. Practicality considerations can be seen from the aspects of ease of use, the efficiency of learning time, and the attractiveness of teaching materials to student interests [18].

The instrument used to collect module practical data is a questionnaire of practicality given to students and teachers. At the evaluation stage group (small group), a questionnaire given to the practicalities of 6 students who have learned to use modules developed. Analysis of practicality questionnaires data at this small group stage shows that the overall developed module has very high practicability with value kappa moment 0.92.

In the large group trial stage (field test), a questionnaire of module practicality was given to students and teachers who accompanied the researcher during the study at both schools. The level of product practicability can be seen by considering whether the product is easy to understand and can be used by teachers and students in normal conditions [19]. The results obtained in both schools from both teacher response questionnaires and overall student responses indicate that the module developed highly practicable. This suggests that the developed module is easy to use, the material delivered is clear, the learning time becomes more efficient, improves the interest and student learning motivation, as well as supporting the role of teachers as facilitators in the learning process. In other words, the developed module is practically used by teachers and students in chemistry learning process in schools for electrolyte and nonelectrolyte solution materials.

The purpose of design the module is trained students to learn independently and to attract students' interest in learning [20]. Module help students to find the concept of the subject matter independently [21]. Learning using colored and pictorial module makes students interested in teaching materials so as to enhance motivation in learning [8]. Generally learning outcomes and student motivation will improve if given good learning conditions and fun. The use of colorful and pictorial modules makes students more passionate and motivated to learn.

In PBL, the learning center is the student, while the teacher acts as a facilitator that facilitating students to actively solve problems and build their knowledge in pairs or in groups [3]. The use of modules developed in the learning process supports the role of the teacher as a facilitator because students must be active to find the concept of the material learned by following the steps of the PBL model contained in the module. The discovery process trains students to learn actively finding problems, preparing hypotheses, planning experiments, analyzing data and making conclusions [22]. The use of modules in learning can help students in improving understanding, making students active in learning activities, and familiarize students to find the concept independently [23].

4. Conclusion

Based on the results of research that has been done, it can be concluded that the PBL module on electrolyte and nonelectrolyte solution to improve critical thinking ability of high school grade X students developed has a very high category of validity and practicability that can be used in the learning process chemistry on electrolyte and nonelectrolyte solutions material.

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