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Development of buffer solution module based on guided inquiry and multiple representations

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Abstract. This research aims to develop a buffer solution module based on guided inquiry and multiple representations and reveal validity, practicality, and effectiveness. This module adapts to the demands of a revised 2013 curriculum that guides students to discover their own concepts and helps students understand the concept of buffer solutions through multiple representations. This type of research is development research, the development model used is the Plomp model which consists of three stages, namely preliminary research, prototyping stage, and assessment phase. The subject of the research was the eleventh grade students. The research instrument used was questionnaire validity sheet, practicality sheet, and learning outcome test. The module is validated by the validator and revised to get a valid module. Valid modules are tested to find out the practicality and effectiveness in the field. The results of the validity sheet analysis show that the module has an average kappa moment of 0.77. This shows that the module is valid with a high category. The results of the field trial showed the practicality of the product based on the teacher's response was 0.73 and the student's response was 0.76. This score includes high criteria. This is evidenced by the product effectiveness test which can be seen from the increase in the initial and final test scores from 18.8 to 84.6. This improvement shows that effective modules are used in the learning process. This is supported by the n-gain value of 0.7 which states that the module is effective with high criteria.

1. Introduction

Chemistry is a part of natural science that studies the composition, properties, transformation of matter and how the composition of a material affect its properties [1]. Buffer solution is one of the chemical materials in the XI class on even semester. Buffer solutions include factual, conceptual and procedural knowledge. In accordance with the revised of 2013 curriculum in 2016, the learning process should guides students to be able to find concepts which means students center learning. In order to find the concept, this curriculum use scientific approach by observing, asking the question, collecting data, associating, and communicating [2]. One of the learning model that apply scientific approach is inquiry learning model.

Inquiry learning model is a learning model that emphasizes critical and analytical thinking processes to find concepts and answers the questionable problem [3]. Inquiry learning places students as subjects of learning. Students are directed to find concepts and answer the question to foster self-confidence while the teacher only acts as a facilitator and motivator for students [4]. There some types of the inquiry learning model, one of them is guided inquiry learning model. Guided inquiry is an inquiry learning model where the teacher asks questions and students answer questions by comparing data and looking for keywords to answer questions [5]. There are five stages of guided inquiry learning, namely the orientation, exploration, concept formation, application, and closing stages [6]. Guided inquiry learning models are supported by suitable teaching materials, one of which is a module. The module is a complete unit consisting of a series of learning activities that are arranged to help students achieve the learning objectives that have been formulated [7]. Guided inquiry-based modules are modules that follow the stages of guided inquiry which are equipped with key questions to help students finding concepts.

Based on the results of the teacher questionnaire and questionnaire analysis of students at SMAN 7 Padang, SMA 5 Padang, MAN 3 Padang, and SMA Pembangunan Laboratorium UNP can be concluded that the teaching materials used are textbooks and student's worksheet which are not able to make students find their own concepts yet. The teaching material also has not used three levels of chemical representation, namely macroscopic, submicroscopic and symbolic. Multiple chemical representations aim to help students find abstract concepts that are difficult to understand without modeling or visualization [8].

The results of research conducted by Bilgin (2009) concluded that students who use guided inquiry in learning are easier to understand concepts [9]. Sunyono (2015) states that the learning process that is supported using multiple representations can improve the mental model or mindset of students [10]. Based on these, we developed a module based on guided inquiry and multiple chemical representations because it has a complete component.

Based on the description above, the objectives of this study are (1) developing a buffer solution module based on guided inquiry and multiple chemical representations, (2) measuring the validity and the practicality of buffer solution modules based on guided inquiry and multiple representations, and (3) measuring the effectiveness of guided inquiry-based buffer solution modules and multiple chemical representations of student learning outcomes.

2. Methods

This study is a research and development (R & D), the research that is used to produce a specific product and test the effectiveness of a particular product (Sugiyono, 2013). The subjects of this study were 3 lecturers of the Department of Chemistry FMIPA UNP, 2 chemistry teachers, the students of class XII of SMAN 5 Padang and 34 students of class XI IPA 2 of SMA 5 Bukittinggi. The product in this study is a buffer solution module based on guided inquiry and multiple representations. The development model used is the Plomp model developed by Tjreed Plomp which consists of 3 stages, namely: (1) preliminary research stage, (2) prototyping stage, and (3) assessment phase [11].

The research starts from the initial investigation (preliminary research). This steps at this stage include needs analysis, curriculum analysis, student analysis, concept analysis, and literature studies. Needs and student analysis is done through interviews with chemistry teachers at SMAN 7 Padang, SMA 5 Padang, MAN 3 Padang, and SMA Pembangunan Laboratorium UNP related to teaching materials used in the learning process. In the curriculum analysis, an analysis of the curriculum and syllabus is used. Literature study is done by finding sources and relevant references to research activities.

The second stage is the design stage and realization of the design results using a prototype approach. The prototyping stage is a small cycle of research with formative evaluation. Formative evaluation is based on the stages of Tessmer's formative evaluation, which consists of four stages: self-evaluation; expert review*;* one-to-one evaluation; small group evaluation; and field test.

Prototype I is self-evaluation using a check list instrument to see the completeness of the components that compose the prototype and the real errors of the prototype. The evaluation results of prototype I was revised to produce prototype II. Prototype II was evaluated by one-on-one test and expert assessment to 3 chemistry lecturers and 2 chemistry teachers. This test aims to obtain the level of validity of prototype II. The results of the evaluation were revised to produce prototype III. Prototype III was evaluated through a small group test of 6 XII class high school students. The results of the prototype III revision produced a valid IV prototype so that a field trial was conducted.

The third stage is the assessment phase of the product being developed. At this stage field trials were carried out. Practicality tests were carried out by giving practicality questionnaires to 2 chemistry teachers and 29 class XII students at SMAN 5 Padang. The effectiveness test is carried out by giving the initial test and final test questions to 34 students of class XI 2 of SMAN 5 Bukittinggi in the form of 20 multiple choice questions consisting of five choices according to the learning objectives. The question has been tested beforehand and an analysis of validity, reliability, differentiation and level of difficulty has been carried out.

The instruments used in this study are validation questionnaires, practicality questionnaires, and learning outcomes consisting of initial and final tests. Validation questionnaires sheets are used to assess modules in terms of content components, presentation components, linguistic components, and graphic components. Practicality questionnaire aims to determine the level of practicality seen in terms of ease of use, efficiency of learning time, and benefits. The data obtained will be analyzed using the Cohen Kappa formula to obtain the kappa moment value. The kappa moment value can be obtained from:

$$\boldsymbol{momen\ kappa\ (k)} = \frac{\boldsymbol{\rho_o - \rho_e}}{\boldsymbol{1 - \rho_o}} \quad (1)$$

Note: k = moment kappa score
$\boldsymbol{\rho_o}$= proportion of realization score
$\boldsymbol{\rho_e}$= proportion of non-realization score

Table 1. Validity Category based on Moments of kappa (k) [12]

interval	Category
0.81 - 1.00	Very high
0.61 - 0.80	Height
0.41 - 0.60	Medium
0, 21 - 0.40	Low
0.01 - 0.20	Very low
<0.00	Not valid

The effectiveness test is done to determine the effectiveness of the module on student learning outcomes. The initial test score and final student test will be analyzed to show student learning outcomes before and after the learning process. Initial and final tests results are analyzed using N-Gain to determine the effectiveness of the module. Learning outcome data can be analyzed using the following formula.

$$g = \frac{\%\text{posttest} - \%\text{pretest}}{100 - \%\text{pretest}} \quad (1)$$

The average of N-Gain scores can be determined by the criteria as presented in the following table [13]

Table 2. Classification of N-gain

scores	Criterion
$g \geq 0.70$	Height
$0.30 \leq g < 0.70$	Medium
$g < 0.30$	Low

3. Results and Discussion

3.1. Preliminary Research

At this stage several steps were carried out namely needs analysis, curriculum analysis, context analysis, and literature study. The results of the needs analysis obtained that the teaching materials used in the learning process in the buffer material are textbooks and worksheets. Both of the materials used have not been in accordance with the revised 2013 curriculum demands which have not used the scientific approach and one of the learning models suggested by the 2013 curriculum. Presentation of material on teaching materials has not yet applied three levels of chemical representation. Based on the results of the questionnaire analysis showed that 65% of students considered the buffer material to be difficult, 55% said the teaching material used was not interesting, and 50% said the teaching material had not been able to guide students in finding the concept independently.

Context analysis is the result of the revised 2013 curriculum syllabus analysis which has been carried out by analyzing Basic Competency (BC) in the material of buffer solution that is BC 3.12. Explain the principle of work, the calculation of pH, and the role of buffer solutions in the living things and 4.12 Make a solution with a certain pH. Indicators of learning are translated from BC and are re-translated into learning objectives.

The results obtained based on literature studies include: (1) the module components used as guidelines in the writing of modules from the Ministry of National Education (2011) and Suryobroto (1983), (2) buffer solution materials referenced from college books and high school chemistry books such as books Chemistry of The Molecular Nature Of Matter Brady (2010) and Chemistry Sudarmo (2014), (3) materials related to guided inquiry were obtained from the journals Hanson (2005), Bilgin (2009), Mathhew (2013), and The College Board (2012) , and (4) material related to multiple representations referenced from the journal Gilbert (2009) and Tan (2013).

3.2. Prototyping Stage

3.2.1. Formation of Prototype

- Prototype I

The prototype one produced in the form a module of buffer solution based on guided inquiry and multiple chemical representations with several components namely cover, preface, table of contents, concept map, module usage instructions, core competencies, basic competencies, indicators, learning objectives, activities sheets, worksheets, evaluation sheets and references. The buffer solution module following the stages of guided inquiry learning includes the stages of orientation, exploration, concept formation, application and closing.

- Prototype II

At this stage formative evaluation is carried out in the form of self-evaluation of prototype I. Based on self-evaluation, the results show that the prototype I requires revision, some key questions have not been able to direct students to find the concept of model analysis and the completeness of the module components, that are the addition of answer keys worksheets and evaluation sheets that have not been formed in prototype I. Revisions made will produce prototype II.

- Prototype III

Prototype III is produced from formative evaluation in the form of one-to-one trials and expert assessment of prototype II. The results obtained in the one-to-one trial evaluation of cover designs and colors make students interested in learning them. The choice of type and font size in the module is appropriate and the language used is easily understood by students. Guided inquiry-based modules have clear and easy to understand learning stages. Models in the form of pictures and tables and key questions can help students find and understand concepts. Expert judgment is carried out by 5 validators to get a valid prototype II. The kappa moment value obtained from module validation for all aspects is 0.77 with a high validity category. Prototype II was revised in several sections such as the addition of symbolic information on submicroscopic, changes in font size in learning objectives, and *layout*. The results of the data analysis module validation of all aspects can be seen in Table 3.

Table 3. The results of the data analysis of the validity of all aspects of being assessed on the module by the validator

No	Category	average value of k	Category validity
1	Content	0.80	High

2	Presentation	0.83	Very High
3	Linguistic	0.76	High
4	Graphical item	0.68	High
	Average	**0.77**	**High**

- prototype IV

At this stage, such a formative evaluation of the prototype III has produced based on small group trials. Based on the results of student questionnaire data analysis, the average kappa moment is 0.75 with a high category. The results of data analysis based on small group trials concluded that the buffer solution module based guided inquiry and multiple chemical representations were easy to use, efficient, and useful for students. Students give advice on small group trials stage to be revised to prototype III so that the prototype IV is obtained with better results than prototype III. The revised parts are explanations on submicroscopic images that are less clear and correct the problem at the application stage.

3.2.2. Assessment. The results of the assessment are practicality data and effectiveness data. Practicality data is obtained from the teacher response questionnaire sheet and student response. The results of the teacher response questionnaire data analysis obtained an average moment of kappa 0.73 and a student response questionnaire analysis of 0.76 in the high category that can be seen in the following table

Table 4. Results of practicality data analysis on all aspects assessed in the module based on the teacher response

No	Category	Average k value	Category Validity
1	Ease of Use	0.73	Height
2	Efficiency Learning Time	0.70	Very High
3	Benefits	0.77	Height
	Average	**0.73**	**High**

Practicality rating on the module is also seen from the student response questionnaire. Here are the results of data analysis.

Table 5. The results of the data analysis of all aspects assessed on a module based on the student's response

No	Category	average value of k	Level of validity
1	ease of use	0.79	High
2	Learning Time Efficiency	0.71	Very High
3	Benefits	0.79	High
	average	**0.76**	**High**

It can be concluded that the buffer solution modules based guided inquiry and multiple representations of chemistry based on ease of use, efficiency of learning time, and the benefits of the module.

The effectiveness data is obtained from the initial and final tests. The score 5 was given to the students who answer questions correctly and score 0 was given to the students who answer question incorrectly. The initial test aims to determine the prior competency of students as a comparison of the final test scores. The final test aims to find out the improvement of student learning outcomes so that the learning objectives are achieved. The following data is the initial test score and the final test of the student in the following table

Table 6. Data description Initial Test and Student Final Test

No.	Name of Student	Initial score	Final Test	N-Gain Value	Criteria
1.	AFFAN M	15	90	0.7	Height
2.	ALVI HIZATI	20	100	0.8	Height
3.	ASQAL M	15	85	0.7	Height
4.	DAVID	15	80	0.6	Medium
5.	DEA	20	80	0.6	Medium
6.	EGA	25	85	0.6	Medium
7.	ELVINA	35	70	0.3	Low
8.	ELVITRA	15	80	0.6	Medium
9.	FARHAN	10	60	0.5	Medium
10.	FARID	10	75	0.6	Medium
11.	FIO	30	75	0.4	Low
12.	HELEN SILVIA	15	90	0.7	Height
13.	BEAUTIFUL K	20	95	0.7	Height
14.	BEAUTIFUL SEPTIA	15	90	0.7	Height
15.	KHAIRUNNISA	20	100	0.8	Height
16.	LAILATUL	20	95	0.7	Height
17.	M .. FAHROZI	25	85	0.6	Medium
18.	M. VACHRU	10	60	0.5	Medium
19.	NAJLA	15	90	0.7	Tinggi
20.	NANDA	10	90	0.8	Height
21.	NAUFAL	15	95	0.8	Height
22.	NOLA	10	100	0.9	Height
23.	NURBAHRI	20	95	0.7	Height
24.	PUTRI	15	100	0.8	Height
25.	RAHMAT	20	95	0.7	Height
26 .	Rahmatul	25	95	0.7	High
27.	RAMADAN	30	85	0.5	Average
28.	raudatul	15	80	0.6	Average
29 ..	rizka	30	80	0.5	Average
30.	SITI HAFIFAH	25	95	0.7	High
31.	SYAFA	20	65	0.4	Average
32.	YUDA	10	65	0.5	Average
33.	YURRIDHO	1 0	75	0.6	Average
34.	ZAHRATUL	'35	75	0.4	Low
Average		**18.8**	**84.6**	**0.7**	**High-Value**

Initial test and final test was analyzed using N-Gain, the value of N-gain is 0.7 with the high category. It can be concluded that the buffer solution module based guided inquiry is effective to improve student learning outcomes in the high category.

3.3. Discussion
This study aims to develop products in the form of buffer solution modules based on guided inquiry and multiple representations. This study uses a Plomp model that consists of three stages: preliminary research, prototype development, and assessment stage. The first stage is preliminary research. Based on the results of interviews, the teacher stated that the teaching material used was not in accordance with the demands of the revised 2013 curriculum. Good teaching materials are teaching materials that can guide students to be active and independent in finding their own concepts, so that the student-centered can be applied [14]. The presentation of the material also does not use three levels of multiple representations, so that macroscopic and symbolic levels can be observed. Learning to use multiple

representation will be maximal if the three levels are well interconnected because they can explain chemical phenomena qualitatively and quantitatively [15]. The results of the student questionnaire analysis stated that the difficulties of buffer solution materials and available materials could not help students in understanding the concept. So that we designed a buffer solution module based guided inquiry and multiple representations in accordance with the 2013 revised curriculum demands.

The prototype formation phase started from prototype I to prototype IV followed by formative evaluation. Formative evaluation based on Tessmer consisting of self-evaluation, expert review, one-to-one evaluation, small group evaluation and a field test. Self-evaluation aims to evaluate products in accordance with the module components according to the Ministry of National Education (2008) and Suryosubroto (1983). Based on the results of self-evaluation, it is necessary to add an answer key. The answer key aims to make students know the size of the student's ability, in accordance with the function of the module which is measuring and assessing students' level of mastery of the material that has been studied [16]. There are several criteria that determine the quality of a product, namely validity, practicality, and effectiveness.

3.3.1. Validity. Test is carried out by one-to-one trials and expert judgment. One-to-one trials are given to students with the aim to find out the interest of student in learning using the developed modules and to figure out students understand of the models and stages of learning to make students find concepts independently. This is in accordance with the purpose of developing buffer solution modules which can guide students to find and understand concepts.

Assessment by experts (validator) is based on four aspects, namely content, construct, linguistic and graphic feasibility. Feasibility of the content aims to find out the modules developed in accordance with the revision of curriculum 2013 and the correct chemical theory. Material presentation is also seen in accordance with the prerequisite material, models, key questions, and exercises with guided inquiry stages. The module must be able to describe Basic Competencies, indicators, and learning objectives to be achieved by students. The feasibility assessment of the construct aims to find out the buffer solution module has been arranged systematically and in accordance with the module components. The purpose of language feasibility assessment is to assess the shape and size of letters, as well as communicative language so that students easily understand the module. In accordance with the supporting theory that communicative language is a language that follows the Indonesian rules of good and right and clear sentences so as not to cause confusion [17]. The language used must be simple, clear, easy to understand, and use general terms [18]. Graphic feasibility assessment aims to assess model design, layout, graphics, and illustrations. According to Sukardi that one of the things considered in the instrument validity is the attractiveness of teaching materials [19]. Validity results indicate that the buffer solution module is valid by fixing several parts of the module.

3.3.2. Practicality. Questioner sheets are given to a small group of 6 students from class XII of SMAN 5 Padang and field trials to 2 chemistry teachers and 29 students from class XII of SMAN 5 Padang. According to Mudjijo (1995), practicality shows the level of ease of use and implementation of products which includes the costs and time in implementation, as well as the management and interpretation of the results [20]. Based on the results of the student questionnaire sheet shows that the buffer solution module is practical in the ease of use with high criteria. It means that the product is a good teaching material [20]. Practicality of teaching materials are seen from time efficient components. The buffer solution module has helped learning become more efficient because students learn according to their respective speeds. In other words that the module helps in measuring the ability of students so that students know the proportion of their mastery of the buffer solution material [17]. Based on the module's benefits component, the teacher shows that it supports the role of the teacher as a facilitator. Similar with Ministry of National Education (2008) states that using learning modules helps students find concepts and increase students' interest independently without relying on others [17]. The results of the teacher and student response questionnaire analysis show that the buffer solution module has been practical by fixing several parts.

3.3.3. Effectiveness. The effectiveness of the buffer solution module is seen from the results of student learning, that is the difference between the initial test and the final test. The effectiveness test was carried out in the field trial phase for 34 students of class XI MIPA 2 of SMA 5 Bukittinggi. The purpose of effectiveness to find out the module is feasible or not, so that the module can be disseminated. Improved student learning outcomes are due to the excess in the buffer solution module. It follows the guided inquiry stage, namely the orientation, exploration, concept formation, application and closing stages. In the orientation phase students are prepared by giving apperception, motivation so that students are interested in learning. The module also presents prerequisite material and basic understanding that can help students in the exploration and concept formation stages.

The second stage is the exploration stage. The exploration and formation phase of the concept is interconnected. At this stage students are given a model in the module, students will observe and analyze so that students can answer key questions. This key question will guide students in discovering concepts so that concept formation occurs. In Hanson's opinion, the key question is the center of guided inquiry activities because it goes through the key questions students actively work to learn new content [6]. This stage also guides students to think critically because students must be able to answer key questions to find concepts. This is supported by Hanson's statement that students must connect between goals, questions and hypotheses to find concepts. Students cannot solve it by ordinary thinking, so students must be required to think critically [21]. The model in the module is present based on multiple representations that help students explain the concept of buffer solutions. In this module, the three level of chemistry representation are exists so that it is interconnected properly which at the macroscopic level show a solution image, in the sub-microscopic present the particles of the buffer solution component and the symbolic level written in the form chemical equation. So that students better understand the concept of chemistry both concrete and abstract. In accordance with the supporting theory that learning using multiple representations will be maximized if the three levels are interconnected well because they can represent chemical phenomena and explain the phenomenon qualitatively and quantitatively [15]. In this activity students must read, see, listen to the teacher's explanation and write it down so that students are more concerned with the concepts learned. This is supported by the opinion of Vernon (1983) that students learn 10% of what is read, 20% of what is heard, 30% of what is seen and heard, 70% of what is said, and 90% of what is said and done [22].

The third stage is the application stage, students work on the questions on the worksheet and evaluation questions so that students understand more about the concepts learned. Based on the results of the analysis of students' answers in filling out the module, the average score of students answering the key question is 88.3, this proves that students have found the concept well and students are given exercises to help students understand the concept. Students answering worksheets are 78.71 and evaluation sheets are 53.75. Evaluation questions answered by students are lower than when answering exercises on the Worksheet. In accordance with Hanson's opinion that training aims to build self-confidence in a simple atmosphere, while the questions are in a complex atmosphere [6].

The last stage is the closing stage. This stage students are asked to write conclusions from the concepts learned. The advantages of a guided inquiry-based and multiple representation buffer solution module help students find concepts independently according to 2013 revised curriculum demands 2016. The buffer solution module can also improve student learning outcomes

4. Conclusion

A valid, practice and effective buffer solution module based on guided inquiry learning model and multiple representation has developed. The results of the validity sheet analysis show that the module has an average kappa moment of 0.77. This shows that the module is valid with a high category. The results of the field trial showed the practicality of the product based on the teacher's response was 0.73 and the student's response was 0.76. This score includes high criteria. This is evidenced by the product effectiveness test which can be seen from the increase in the initial and final test scores from 18.8 to 84.6. This improvement shows that effective modules are used in the learning process. This is supported by the n-gain value of 0.7 which states that the module is effective with high criteria.

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