JKPK (JURNAL KIMIA DAN PENDIDIKAN KIMIA), Vol. 6, No. 2, 2021 pp. 228-241
Chemistry Education Study Program, Universitas Sebelas Maret ISSN 2503-4146
https://jurnal.uns.ac.id/jkpk ISSN 2503-4154 (online)

THE DEVELOPMENT OF STRUCTURED INQUIRY WITH THREE-LEVEL REPRESENTATION MODULE

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Received: July 23. 2021 Accepted: August 29, 2021 Online Published: August 31, 2021
DOI : 10.20961/jkpk.v6i2.53945

ABSTRACT

Mole concepts are essential parts of chemistry learning and have become preliminaries to learn other chemistry concepts. However, the learning resource used has not incorporated three representations, resulting in students' learning outcomes. This study aimed to develop a structured inquiry module in terms of validity and practicality. The method used in this study is research development through the use of the Plomp model. There were 141 senior high school students in Padang participating in the study. The instruments of this study included cognitive tests. The result of the study indicated that the structured inquiry module had high validity (V=0.98), practicality based on teachers' response (P=0.36) and students' response (P=0.36).
Furthermore, the result of the t-test toward hypotheses of the learning outcome of the mole concept showed that the learning outcome of the mole concept in experimental groups was higher than that of control groups at both schools. Hence, the structured inquiry module has high validity and practicality. It is also effective to be used in chemistry learning at school. The module developed is a module with three levels of representation (macroscopic level, submicroscopic level and symbolic level). The module contains structured inquiry activities. The module also includes several components such as teacher guidelines, student activity sheets, worksheets, worksheet keys, test sheets, test sheet keys.

Key words: *Inquiry Structured, Module, Three Level Representation*

PENDAHULUAN

The mole concept is the basic concept learnt by senior high school students. [1]'There is probably no concept in the first-year chemistry subject that is more important for students to understand than substance (moles). One of the main reasons the concept of the amount of substance (mole) is so important in chemistry is stoichiometry. [2]–[4] stated that stoichiometry is a concept that is fundamental or important for understanding more complex chemical concepts. The most important part that students must understand in studying stoichiometry is the amount of substance (mole).

The concept of a mole is abstract. The mole presents an abstract concept at the atomic/molecular level that will be difficult for students. For example, 6.02 X 10^{23}, the experimentally measured mole value, is abstractly a large quantity value. In addition, basic level knowledge must be obtained through algorithms, but deeper understanding requires factual and procedural knowledge beyond algorithms [5]. In the end, the mole is the link between the macroscopic level and the atomic/molecular level.

However, the fact shows that many high school students think that substance is difficult to understand. The reason students have difficulty in understanding the concept of stoichiometry is that students are less skilled in solving numerical problems or mathematical reasoning [6]–[8], and students cannot connect the three levels of representation as a whole, namely the macroscopic, microscopic, and symbolic levels [9]–[12]. This difficulty can come from the way of teaching[13], [14] or the textbook[15], [16] used by the teacher. In the learning process, a teaching strategy and appropriate media are needed. Whether it is direct teaching or the media significantly used affects how students understand chemistry[17]. Direct teaching and the model presented through the textbooks significantly affect students' understanding[18], [19]. Textbooks are one of the learning resources used by teachers in the teaching and learning process.

Chemical concept presented in textbooks often causes errors, causing misconceptions in students and students' difficulties in understanding chemical concept[20]. The previous study [21]has shown that to improve students' understanding, textbook writers and teachers need to be aware of how the model is presented, and which representations may be the source of students' difficulties in understanding. Teaching will be more effective when teachers better understand students' learning difficulties, and there are more representations and activities they can use.

The research focuses on analysing textbooks on the mole concept, [22]investigating 13 advanced chemistry textbooks commonly used in Italian schools. According to.[22], the term mole is only a synonym for gram-molecule in most texts; some texts give incorrect definitions; one other text presents the opposite definition. The results of the analysis [23] of textbooks in 29 high schools and colleges showed that the textbook authors defined the mole as a particle of 6.02×10^{23}; and a term of ^{12}C.

The learning resource developed in this research is a structured inquiry-based module. Structured inquiry is an activity that involves students in "hands-on" activities, collects and organizes data, writes conclusions but follows a series or sequence correctly from the instructions and procedures are given by the teacher or textbook [24]. Thus, the structured inquiry is when the teacher gives students a “hands-on” problem to investigate [25]. Furthermore, methods and concepts are used for the investigation activities.

Although there is research on module development, it is very limited for research on module development using three levels, especially on the mole conceptt. So the use of three levels of representation is essential because it can provide benefits for overcoming students' learning difficulties and strengthening students' understanding[26]. [27]Reported that ability in algorithmic problem solving was not interpreted as conceptual understanding ability. If this fundamental 'level of representation' is not understood, learning topics like solution concentration concepts can hinder learning.

The concept of mole (amount of substance) is a concept that connects the macro world with the micro world.

Several studies have been conducted regarding student learning difficulties, alternative conceptions and problem-solving strategies on the mole concept. For example, [28]Teaching stoichiometry focuses on a level of symbolic representation that relies heavily on algorithms that do not develop conceptual understanding.[5] stated that students have two shortcomings: the inability to obtain meaning between the macro and sub-micro levels when solving problems and inadequate understanding of the concept and use of algorithms and rules[29-30].

There have been several studies on the development of inquiry-based learning. However, those studies are limited to the development of inquiry activities in which the activities themselves are the standard ones. Another study only focused on using laboratory activities without facilitating the learning activities by connecting the three levels of representations. So we need a teaching concept with three levels of representation and guide students to carry out "hand-on" activities such as in the structured inquiry stage to understand the learning concept better.

METHODS

The type of research used in this research is *Research and Development* (R&D). The development model used in this study uses the Ploomp model design as developed by TjreedPlomp. This model consists of 3 stages: preliminary research, development or prototyping, and assessment [31]. At each stage, there is a formative evaluation.

Preliminary Research is when needs and context analysis are carried out, a literature review, and a conceptual framework is developed. The prototyping stage aims to design a product from the problems identified in the initial investigation stage. Product development is carried out at this stage and then iterations (microcycles) using formative evaluation developed by Tessmer[32]to improve and revise the product. The assessment phase is the final stage of research to conclude whether the product developed can overcome the problems that have been identified.

Participants for the test in developing a structured inquiry-based module on the mole concept and reaction equations are first-year students at two high schools in Padang, West Sumatra. And two chemistry teachers as practitioners to operate the developed modules. The resulting product is a structured inquiry-based module using three levels of representation.

The type of instrument used in the study was a validation sheet questionnaire and a practicality sheet questionnaire. Validation sheet questionnaires were given to four experts in their fields (content, construct, linguistic and graphic). The validation sheet contains 23 aspects of the assessment: a content component, a construct component, a linguistic component, and a graphic component.

Aiken formula was employed to analyze the content validity. The formula is as follows[33]:

$$V = \sum s / [n(c-1)]$$

Information:

s : r-lo

lo :the lowest validity

c :the highest validity

r :the value given by rater

n :numbers of raters

Aiken value V is ranged from 0 to 1. The higher the V score shows the high value of content validity. If V score is 0,60< V < 0,80,the criteria is high. It means it is valid in terms of content, language, construct and graphics. The validity category according to Aiken's V is presented in Table 1[34].

Table 1. Validity category based on Aiken's V

Aiken's V scale	Category
V ≤ 0,4	Less valid
0,4≥V ≤ 0,8	Current valid
0,8<	Very Valid

The practical analysis aims to determine whether the developed module meets the practicality criteria. The device's practicality was analyzed based on teacher and student assessments' data in the small group and field tests. The practicality analysis is carried out by converting the data results into Table 2 [35].

$$\text{Practicality} = \frac{\text{Gained Score}}{\text{Number of Raters}}$$

Table 2.Practicality category

Interval score	Category
3.6 ≤ P < 4.0	Very practical
2.6 ≤ P < 3.5	Practical
1.6 ≤ P < 2.5	Less practical
1.0 ≤ P < 1.5	Impractical

RESULTS AND DISCUSSION

This study aims to determine the level of validity and practicality of the product developed, namely a structured inquiry-based module using three levels of representation on the amount of substance (mole) concept for first-year students in high school. There are three stages to produce a valid and practical module: preliminary research, prototyping, and assessment.

Preliminary Research

This stage aims to get an overview of the product's characteristics developed to be used in the learning process. The main steps taken are analysis of problems and needs, curriculum analysis, concept analysis and student analysis. The findings at this stage, such as the amount of substance (mole), used the teaching method of lectures, discussions, and questions and answers in the learning concept. Based on the semi-structured interview analysis results with the questions given, namely about the learning methods used by the teacher during the mole concept learning process, it showed that 52% of teachers used the lecture learning method, 34% discussion and 14% discussion question and answer. Students often face problems during the learning process in solving problems solving calculations or mathematical reasoning[36], [37].

The analysis results from semi-structured interviews regarding whether students can understand the mole concept and what difficulties students experience during learning the mole concept show that 84% are difficult to understand and 16% are easy to understand. There are several reasons for students' difficulties in understanding the mole concept, students tended to memorize formulas to solve calculation problems and had difficulty determining mole units. In general, the contents or teaching concepts in the textbooks used by teachers and students are complete. Chemical representations have not been drawn for the mole concept topic, especially at the submicroscopic level[38]. The analysis results regarding whether the mole concept has been explained by atomic/molecular modeling as much as 11% during the learning process, the concept has been explained symbolically 100%. So that if students cannot connect the three levels of chemical representation as a whole, it will affect students' understanding of chemistry learning concepts [39].

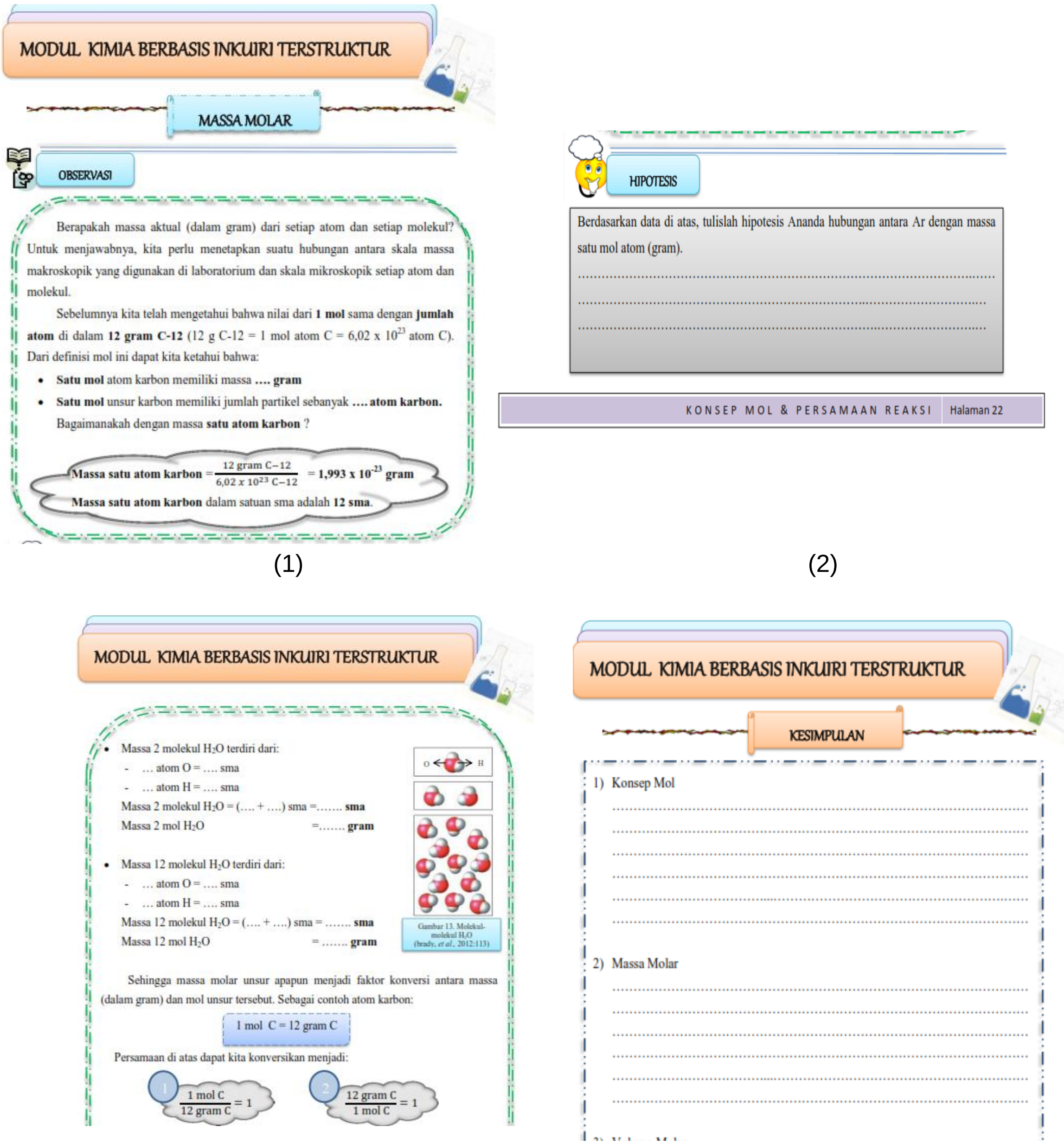
Development or Prototyping Phase

Based on the findings at the preliminary research stage, a module was designed based on these findings. The results of the design and investigation stages that have been carried out are called prototype 1.Prototype 1 was developed in the form of a structured inquiry-based module for mole concept which is arranged according to the syntax of a structured inquiry learning model. The components of the designed module are cover, preface, table of contents, list of pictures, instructions for using the module, competencies, subject matter, concept maps, activity sheets, worksheets, evaluation questions, answer keys and references.

After obtaining Prototype 1, a self-evaluation was carried out to produce Prototype II. This self-evaluation focuses on obvious errors such as typing letters, using images, and module completeness, such as the elements that a module must have and the stages in the structured inquiry learning model. Some display module components can be seen in Figures 1 and Figures 2.

(1) (2)

Figure 1.Component on model (1) cover of module (2) the content of module



(3) (4)

Figure 2. The steps of structured inquiry activities: 1) Observation; 2) Hypotheses; 3) Data Collections; 4) Conclusion

Experts (lecturers) validated the resulting prototype II was validated by experts (lecturers), and an individual evaluation (one-to-one evaluation) was carried out on three first-year high school students. Validation includes four components; content components, construct components, linguistic components and graphic components. The results of the content component analysis using the Aiken V scale show that all aspects of the content components in the Current Valid category can be seen in Table 3.

Table 3.Results of Content Component Assessment

Aspects	Aiken's V scale	Category
Conformity of the content of the module with KI, KD, indicators and learning objectives	0,75	Current Valid
The suitability of the module with the concept being taught	0,83	Valid
Conformity of questions to find concepts	0,83	Valid
Suitability of practice with concept	0,83	Valid
The suitability of the use of the macroscopic level with the concept being taught	0,75	Current Valid
The suitability of the use of the microscopic level with the concept being taught	0,75	Current Valid
The suitability of the use of the symbolic level with the concept being taught	0,75	Current Valid
The truth of the substance of the learning concept	0,83	Valid
Benefits for comprehension	0,75	Current Valid
Average	0,79	Current Valid

The results of the construct component assessment data analysis by the validator can be seen in Table 4. The results of the linguistic component analysis show that all aspects have very high validity. The mean score of Aiken's V scale for construct components is 0.88 with a very high validity category.

Table 4.Results of Construct Component Assessment

Aspects	Aiken's V scale	Category
Clarity of learning objectives and indicators to be achieved	0,92	Very Valid
The systematics of module preparation is adjusted to the components that make up the module	0,83	Very Valid
Systematic module preparation based on the steps of the Structured Inquiry model	0,92	Very Valid
The observation stage can explore students' prior knowledge	0,83	Very Valid
Hypothesis stage to guide students to formulate questions for investigation	0,92	Very Valid
The data collection and collection stage guides students to find concepts through questions and information data	0,92	Very Valid
The conclusion stage leads students to make data conclusions and findings	0,83	Very Valid
Average	0,88	Very Valid

The results of the linguistic component assessment data analysis by the validator can be seen in Table 5. The results of the linguistic component analysis show that all aspects have very high validity.

The mean score of Aiken's V scale for the linguistic component of prototype II module concept mole was 0.97 with a very high validity category.

Table 5 .Results of the Assessment of Language Components

Aspects	Aiken's V scale	Category
Readability of writing and images contained in the module	1,00	Very Valid
Clarity of information in the module	1,00	Very Valid
Compatibility of writing rules with correct Indonesian grammar rules (spelling accuracy, punctuation, terms and sentence structure)	0,92	Very Valid
The language used is easy to understand	1,00	Very Valid
Effective and efficient use of language (clear and concise)	0,92	Very Valid
Average	0,97	Very Valid

The results of the data analysis of the assessment of the graphic component by the validator can be seen in Table 6. The results of the graphical component analysis show that all aspects have very high validity. The mean score of Aiken's V scale for the graphical component of prototype II of the mole concept module is 0.98, with a very high validity category

.Table 6.Results of Graphical Component Assessment

Aspects	Aiken's V scale	Category
Use of font type and size	1,00	Very Valid
Layout of module	1,00	Very Valid
The image on the model can be seen clearly	1,00	Very Valid
Design and color on the cover of the module	0,92	Very Valid
The design and color on the module sheet	1,00	Very Valid
Average	0,98	Very Valid

Table 7 shows the results of the analysis of the four components of the assessment of the prototype II module, namely the content, construct, linguistic and graphic components, the Aiken's V scale of 0.91 was obtained with a very high validity category

.Table 7.The Result of Prototype II Assessments Result

Aspect	Aiken's V scale	Validity Category
Content	0,79	valid
Construct	0,88	Very Valid
Language	0,97	Very Valid
Graphic	0,98	Very Valid
Average	0,91	Very Valid

After revision, prototype III was produced. Prototype III resulted from an expert review (expert review) and individual evaluation (one-to-one evaluation) of prototype II. An individual evaluation (one-to-one evaluation) was conducted through interviews with three students in the first year of high school A with low, medium and high abilities. Three aspects are evaluated at this stage, namely clarity, appeal and obvious errors. Based on the interviews conducted, it was found that the cover display already represented the module's content for the mole concept. Instructions for using the module can be understood well, the presentation of the content in the module is clear. The language used in the module is easy to understand. The pictures and colors in the module attract students' interest, and students can understand the steps of learning using the module.

During the one-on-one evaluation, students with low abilities still have difficulty in solving the problem of calculating 1 mole of a substance (as seen from the figure 3). Students' misconception lies at the submicroscopic level. There are still students who do not understand that 1 mole of a substance represents the number of substances that contain the same number of particles as the number of particles in 12 grams of C. -12. The sample's ratio between moles and particles is defined as an indirect means of counting the atomic/molecular particles utilizing a macroscopic mass sum.[5]

The definition of mole indicates that the mole has both quantitative and conceptual calculations. Research in science education shows a quantitative understanding of moles[40],[41]. While understanding the mole conceptually, students must be able to perceive the macroscopic world they see in reality as a number and relate it to the world of particles [42]

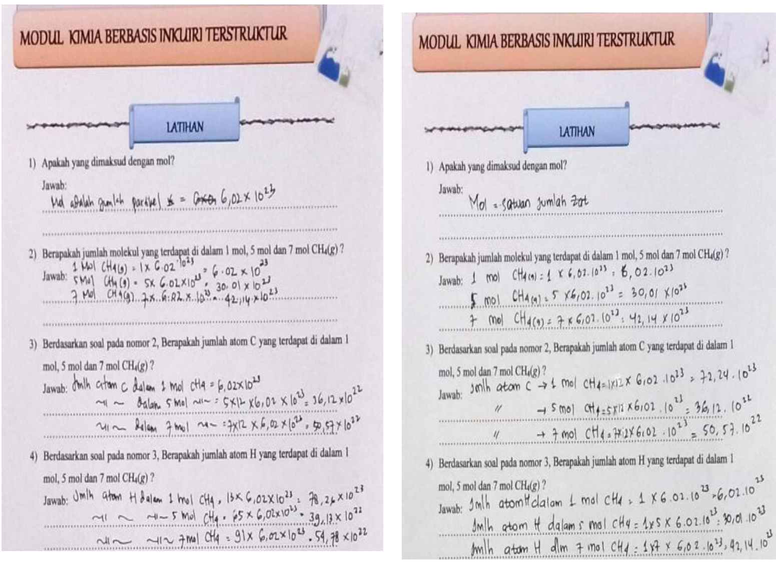


Figure 3.Students' answers related to 1 mole on the worksheet

Prototype IV was obtained after conducting a small group evaluation of prototype III. This small group evaluation was carried out by teaching the mole concept to nine students with high, medium and low abilities in the first year of high school A. Each student received one module design. The purpose of the small group evaluation is to test the practicality of the developed module. Learning using modules is designed for one meeting.

At the end of the learning, session students fill out a questionnaire related to the use of modules in the learning process.This questionnaire aims to see the practicality of the module in small group evaluation. Aspects assessed in this small group evaluation are appeal, ease of use, the efficiency of learning time and benefits of the module. The results of the practicality of students at the small group evaluation stage can be seen in Table 8. The results of the student practicality questionnaire show that aspects of the appeal, ease of use, learning time efficiency and module benefits have a very high level of practicality.

Table 8.The Result of Practicality on Small Group

Aspect	Interval score	Category
Appeal	3,5	practical
Ease of Use	3,5	Practical
Time Efficiency	3,4	Practical
Benefit	3,5	Practical
Overall Practicality	3,5	Practi-cal

Overall, Table 8 shows the results of the student practicality questionnaire obtained an interval score of 3.6 (in the practical level) for the module. The data obtained from the validity test,

effectiveness test is important because the teaching concepts developed can only be used in the learning process after being tested for validity, practicality and effectiveness[43]. After evaluating small groups, prototype IV was obtained, which was tested in large groups (field test).

Assessment Phase

The assessment phase aims to determine the practicality and effectiveness of the modules tested in large groups (field testing). The large group trial was conducted at two high schools in Padang, SMA A Padang (high criteria) and SMA B Padang (medium criteria). In each school, there are two sample classes, namely the experimental class and the control class. The experimental class uses the developed module, while the control class uses textbooks from school. After carrying out the module's learning process, practical data were obtained from giving students (student response questionnaires) and chemistry teachers (teacher response questionnaires). **The practicality of the Module from Student Response Questionnaire**

Seventy-one students filled out the student response questionnaire after learning using the module. The results of the practicality data analysis of the module at the field test stage can be seen in Table 9. The average interval score gain for the practicality of the student response questionnaire is 3,5 with a practical level.

practicality test and effectiveness test on research subjects are beneficial to produce a quality module. The product developed is of high quality if it meets the valid, practical and effective criteria[31]. Validity, practicality and

Table 9.Student Practical Results at the Field Test Stage

Aspect	Interval Score	Category
Appeal	3,7	Very Practical
Ease of Use	3,5	Practical
Time Efficiency	3,5	Practical
Benefit	3,5	Practical
Overall Practicality	3,5	Practical

The practicality of the Module from Teacher Response Questionnaire

Two chemistry teachers filled out the teacher response questionnaire after learning using the module. Aspects assessed include ease of use, the efficiency of learning time, benefits and attractiveness of teaching concepts to students' interests according to the teacher's opinion. The results of the practicality data analysis of the module can be seen in Table 10. The average acquisition of interval score for practicality from the teacher's response questionnaire is 3.6 (very practical), meaning that the structured inquiry-based mole concept module developed is practically used in the learning process by the teacher

Table 10.The Result of Practicality from Teacher

Aspect	K	Category
Appeal	3,5	Practical
Ease of Use	3,9	Very Practical
Time Efficiency	3,5	Practical
Benefit	3,6	Very Practical
Overall Practicality	3,6	Very Practical

In addition to finding out the module's practicality level, the large group trial (field test) also aims to determine the effectiveness of the designed module. The effectiveness of this module can be seen from the effect of using the module on student learning in the control and experimental classes.

Student Activities in Working on Modules

Using the module on student activities in working on the module, namely in the form of student answers, is one aspect to determine the module's effectiveness. Students' answers that are assessed are directly related to the use of the designed module. Aspects that are considered in assessing student answers are student activities in observing pictures and analyzing problems. In addition, to answer problem formulations and write hypotheses (visual activities, writing activities), answer questions in the module to find concepts (mental activities, writing activities), make conclusions (mental activities, writing activities), and do exercises (mental activities, writing activities). Writing activity). Students are said to have carried out these activities if students fill out the module correctly on the answer sheet provided.Table11 shows a summary of the percentage of students' answers in working on modules at High School A and B.

Table 11.Summary of Percentage of Students' Answers

Students' Answers	% Students' answers			
	High School A		High School B	
	Mean	Category	Mean	Category
Observing pictures and analyzing problems to answer problem formulations and writing hypotheses	92,14	Very Effective	87,86	Very Effective
Answering questions in the module to find concepts	92,50	Very Effective	86,78	Very Effective
Making conclusions	91,43	Very Effective	86.07	Very Effective
Doing exercise	91,42	Very Effective	87,14	Very Effective

Learning Outcomes

Experimental research was conducted in a large group trial (field test) with a sample of 2 classes in each school (namely the control class and the experimental class). The sample selection was carried out by purposive cluster sampling. Normality and homogeneity tests also carried out the determination of the control class and the experimental class

.The effect of using the module on student learning outcomes can be seen from the final test given to the control class (without using the module) and the experimental class (using the module) after studying the mole concept by testing hypotheses. Before testing the hypothesis, normality and homogeneity tests were carried out on the sample class based on the final test scores obtained by students. Based on the data analysis that has been done, it is known that the control class and the experimental class are normally distributed and homogeneous*. T*he t-test is used to test the hypothesis with the help of SPSS software. The data on the results of hypothesis testing can be seen from Table 12.

Aspects that are considered in assessing student answers are student activities in observing pictures and analyzing problems. In addition, it is also to answer problem formulations and write hypotheses (visual activities, writing activities), answer questions in the module to find concepts (mental activities, writing activities), make conclusions (mental activities, writing activities), and do exercises (mental activities, writing activities). write).

Table 12.Hypothesis Test Results on Learning Outcomes of Sample Class

School	Group	N	Mean	S	Sig.	Ket.
High School A	Experimental	35	85,49	8,716	0,030	H_0 was
(High)	Control	36	80,86	8,903		rejected
High School B	Experimental	35	79,06	8,678	0,005	H_0 was
(Medium)	Control	35	72,54	9,921		rejected

Table 11 shows that the significance value obtained at High School A Padang is 0.030 at the 95% confidence level with a significance level (α = 0.05). The significance value is smaller than 0.05 so that H0 is rejected and H1 is accepted. That is, there is an effect of using the module on student learning outcomes in the experimental class and the control class. The significance value obtained from hypothesis testing for student learning outcomes at High School B Padang (Sig. = 0.005) is also smaller than 0, so H0 is rejected, and H1 is accepted. That is, there is an effect of using the module on student learning outcomes in the experimental class and the control class.

CONCLUSION

The structured inquiry-based chemistry module to improve students' mental models regarding the mole concept and reaction equations for the first-year high school student has met the valid, practical and effective criteria. Thus this module can be used as one of the teaching concepts in the learning process on the mole concept. Furthermore, using this module can help students learn independently or in groups and actively find their concepts to build knowledge through structured inquiry activities.

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