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DEVELOPMENT OF CHEMICAL LEARNING MODULE BASED ON MULTIPLE REPRESENTATIONS OF REDOX MATERIALS

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Abstract
The limited teaching materials used in the learning process at School make students experience difficulties in the learning process, especially using teaching materials for independent learning. This study aims to develop and analyze the quality of a chemistry learning module based on multiple representations of redox material. The type of research used is research and development using a 4D model (four-D model) adapted from Thiagarajan. The stages of the 4D Model include the define stage, the design stage, the developing stage, and the disseminated stage. However, this study was only limited to the development stage. The quality of the product was assessed by three material experts, three media experts, and two reviewers (chemistry educators) and in response by thirty-two students of Grade 9 High School Science Class. Quality assessment was carried out using a Likert scale questionnaire sheet, and student responses were carried out using a Guttman scale questionnaire sheet. The results of the research validation show that the chemistry learning module based on multiple representations of redox material is feasible to be used as teaching material. This can be seen from the percentage of ideals achieved from validating all aspects of material experts, media experts, and reviewers (chemistry educators), namely, 91.6%, 94.7%, 81.25%, with excellent categories, and students respond positively to the module.

Keywords: Teaching materials, modules, multiple representations, redox.

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INTRODUCTION

The results of interviews conducted with chemistry subject educators at Madrasah Aliyah eL-BAS Ciamis in September 2021 found that one of the problems experienced was that the use of chemistry teaching materials was still limited to textbooks in students having difficulty learning independently when there was material that was not yet available. Understood when learning in class. Coupled with boarding schools that do not allow students to bring electronic devices, it is difficult for students to find learning resources from various references. Lack of learning resources results in reduced student interest, especially for chemistry lessons that use many formulas, making them more challenging to understand. Restiyani (2016) stated the results of his research that chemistry is one of the subjects that are less attractive because the material is abstract.

The Ministry of National Education (2008) explains that chemistry studies the structure, composition, properties, changes in matter, and the energy that accompanies these changes. Chemistry has several characteristics that distinguish it from other sciences. According to Nastiti et al. (2012), some complex concepts and phenomena are abstract and unobservable in chemistry. An essential feature of chemistry is matter interaction at the macroscopic, submicroscopic, and symbolic levels. These three levels make most chemistry lessons difficult for students to understand (Sunyono, 2012). So, there needs to be an effort to make the abstract chemical material more concrete through representation (Mashami & Ahmadi, 2015).

Based on the chemistry characteristics, chemistry will be easy to understand if it can be represented in three levels: macroscopic, submicroscopic, and symbolic (Adadan, 2013). the appearance of particles at the submicroscopic level will result in a better understanding (Williamson et al., 2012). The results of research conducted by Achmaliya, N (2016) on the development of a chemical representation-based module on collision theory material obtained research results that the module developed was valid and practical after an assessment was carried out.

The results of interviews with chemistry educators also found that oxidation-reduction (redox) reactions were one of the difficulties for students in class X School. This is because redox is one of the disciplines of chemistry, is characterized by specific symptoms uses logical mathematical calculations, and requires symbolic memory, understanding, application, and events that often occur in everyday life (Pratiwi et al., 2014).

In improving the learning process, teachers must make the learning process more innovative and optimal to encourage students to learn independently and guide learning in the classroom. The role of teachers, students, and learning media is constructive in the learning process. Media is needed in the learning process because, in essence, the teaching and learning process is a communication process, delivering information from the introduction to the recipient (Munadi, 2013). Therefore, teachers need to be able to choose and determine the learning media that will be used to achieve the learning objectives as well as possible (Tafonao, 2018).

According to Edgar Dale (1969), teaching materials can be formulated as things that can be used to support and facilitate the learning process (Sitepu, 2014). Teaching materials include everything that can be used to help everyone learn and demonstrate their abilities. Karwono & Mularsih (2017). The material is beneficial for both teachers and students during the learning process. With this material, the impact of learning on students also increases (Firaihanil, 2018).

One of the teaching materials that can be used in the learning process is a module, a form of teaching material designed so that students can learn independently (Asyhar, 2012).

This module allows students to test themselves through the exercises provided (Daryanto 2014). Modules play an essential role in learning. Students have the opportunity to train themselves to learn independently, students can express how to learn according to their abilities and interests, and students have the opportunity to test their abilities through the exercises provided in the module (Mulyasa et al., 2019).

Based on the facts of the problem found by the researcher, the researcher intends to develop a chemistry learning module based on multiple representations of redox material at Madrasah Aliyah eL-BAS Ciamis. This module contains redox material for class X, which presents three levels of chemical representation, namely macroscopic, submicroscopic, and symbolic, which are expected to help students in the learning process.

METHODS

This type of research is Research and Development (R&D) with a 4-D Development Research Model (4-D Model). According to Sukmadinata (2013), development research is a method used to develop new products or improve existing products. This study uses a 4-D research model developed by S. Thiagarajan, Dorothy S. Semmel, and Melvyn I. Semmel (1974), covering, defining, planning (designing), developing (developing), and disseminating (disseminate), which is only enforced until the development stage.

The 4-D Model is carried out in the defined stage, where an initial analysis is carried out to determine the problems faced. This stage is carried out to describe everything that is needed in the field so that researchers can find out the problems that will be faced and their solutions (Karim, 2022). several stages are carried out. Namely, a needs analysis carried out by conducting interviews with chemistry educators, an analysis of the curriculum and materials used to examine the curriculum, and materials to be used. The curriculum used is the 2013 curriculum and the material presented is redox class X.

The next stage is the design stage. According to (Dian & Sri, 2017), the design stage is the stage that intends to prepare and produce a prototype draft module. Several stages were carried out, namely the selection of the format using the format according to the National Education Standards Agency (BSNP) and the book center in the form of the module size used was B5. The selected font was Poppins. The collection of reference material to be presented was taken from various valid sources such as high school/MA chemistry books. Moreover, the official website makes data collection instruments referring to module quality standards according to the National Education Standards Agency (BNSP) so that several aspects are produced, including content feasibility, language feasibility, presentation, graphics, module characteristics, and multiple representations, and the final stage is making a design. The beginning of the module contains a cover, introduction, technical use of the module, and a description of the material.

The t-develop stage is an activity that includes the formation of product designs and repeated product verification tests until the product is produced as specified. Thiagarajan divides the development stage into two activities, expert validation and development trials (Rhamdany, 2017). Then according to Andari & Lusiana (2016), the development stage intends to produce a revised product draft based on expert input and data obtained from the trial (final draft). The development stage was revision I (Draft II) based on the comments and suggestions of supervisors and peer reviewers. Validation of research instruments aimed to ensure that the research instruments made were valid and suitable for research and by the aspects to be measured (Ernawati & Sukardiyono, 2017)—followed by product validation of Amendment I (Draft II) to material experts and media experts to produce comments and recommendations for revisions to the product and Production Revision II (Draft III). The inputs, the chemistry educator, and student responses then validated the suggested results to produce Revision III (Draft IV).

The validated results are qualitative data in the form of input and suggestions for module improvement. The quality assessment results are quantitative data obtained from scores from the Likert scale, namely excellent = 4, good = 3, less = 2, and least = 1. According to Sugiyono (2018), the Likert scale measures attitudes, opinions, and perceptions of a person or group. Student response data is qualitative data obtained from student responses in the form of values from the Guttman scale with the statements "Yes" and "No." The Guttman scale is a scale used to obtain positive answers from respondents. That is, there are only two intervals such as "agree-disagree"; "Yes or no"; "right and wrong"; "positive and negative"; "never," etc. The measurement scale can produce multiple-choice questions and checklist-style, with answers given a maximum (agree) 1 and a minimum (disagree) zero (Sugiyono, 2014)

The feasibility of the module can be seen from several aspects, namely the feasibility of the content, the feasibility of language, multiple representations, graphics, presentation, module characteristics, and practicality. The results of the data obtained are used as an essential reference to determine the quality of the developed module.

RESULTS & DISCUSSION

Results

This research was conducted in Grade 9 High School Science Class. The research results are divided into a development process in the form of input and suggestions from supervisors and peer reviewers, the results of validation development products from material experts, media experts, and chemistry educators, and the responses from students to the developed module.

Define stage

The needs analysis was carried out by conducting interviews with chemistry educators at the School; it was found that the limited teaching materials used meant students did not have independent learning resources. The facts from the interviews that had been obtained were analyzed and used as the defining stage.

Design stage

Several stages are carried out at the design stage, which produces an initial module design that the supervisor and peer reviewer will review. The initial design of the module can be seen in Figure 1.

Figure 1 Initial Design of the Module

Develop stage

At the module development stage, it is reviewed by the supervisor and three peer reviewers (chemistry education students). Instrument validation is carried out by one instrument expert lecturer and product validation by three material expert lecturers, three media expert lecturers, two reviewers (chemistry educators), and responded by 32 learners.

Validation Stage

Product validation is carried out through the following stages:

Product validation by a materials expert

Three material experts were validated by filling out a quality assessment form, which was then converted into quantitative data and tabulated and analyzed to determine product quality. Aspects that are validated are aspects of content feasibility, aspects of language feasibility, and aspects of chemical representation. The table of material expert validation results can be seen in Table 1.

Table 1 Validation results by material experts

Aspect	Ideal percentage (%)	Category
Content eligibility	93,75%	Excellent
Language eligibility	83,3%	Excellent
Chemical representation	100%	Excellent
Total	91.6%	Excellent

The results of the validation by material experts as a whole have an average score of 33 with a maximum ideal score of 36 and an ideal percentage of 91.6%, including the excellent category.

Product validation by media experts

Three media experts validated by filling out a quality assessment form, which was then converted into quantitative data and tabulated and analyzed to determine product quality. Aspects that are validated are aspects of presentation, aspects of graphics, and aspects of module characteristics. Table, The results of media expert validation can be seen in Table 2.

Table 2 Validation results by media experts

Aspect	Ideal percentage (%)	Category
Presentation	97,2%	Excellent
Graphics	91,6%	Excellent
Module characteristics	95%	Excellent
Total	94,5%	Excellent

The validation results by media experts have an average score of 41.6 with an ideal maximum score of 44 and an ideal percentage of 94.5%, including the excellent category.

Product validation by the reviewer (chemistry educator)

Two chemistry educators validated at School by filling out a quality assessment form, which was then converted into quantitative data, tabulated, and analyzed to determine product quality. Aspects validated are content feasibility, language feasibility, presentation aspects, visual aspects, module characteristics aspects, and multiple presentation aspects. The table of validation results for chemistry educators can be seen in Table 3.

Table 3 Results of validation by chemistry educators

Aspect	Ideal percentage (%)	Category
Content eligibility	75%	Excellent
Language Eligibility	79%	Excellent
Presentation	75%	Excellent
Graphics	100%	Excellent
Module Characteristics	80%	Excellent
Multiple representations	81,2%	Excellent
Total	81,25%	Excellent

The validation results by two reviewers overall have a total average score of 65 with a maximum ideal score of 80 and an ideal percentage of 81.25%, including the excellent category.

Student Response to the final product of the module

Thirty-two students of Grade 9 High School Science Class responded to the student response questionnaire. The response questionnaire comprises six aspects: material aspects, presentation, language, design, practicality, and multiple representations. Assess student responses using the Guttman scale with the answer choices "Yes" and "No." The table of the results of student responses can be seen in Table 4.

Table 4 Student response results

Aspect	Ideal percentage (%)
Theory	98.6%
Presentation	100%
Language	100%
Design	98%
Practicality	92%
Multiple representations	100%
Total	98,3%

The results of student responses showed a positive response with the percentage of ideals achieved, namely 98.3%.

Discussion

The final result of this development research is a product in the form of a chemistry learning module based on multiple representations of redox material for SMA/MA class X. The product developed is a printed module made using Microsoft Word and Corel Draw software. The material in this product was developed according to KI and KD in the 2013 curriculum. This module product contains oxidation-reduction reaction chemistry (Redox), which is presented with various representations, namely macroscopic, submicroscopic, and symbolic. The display of the contents of the module can be seen in Figure 2.

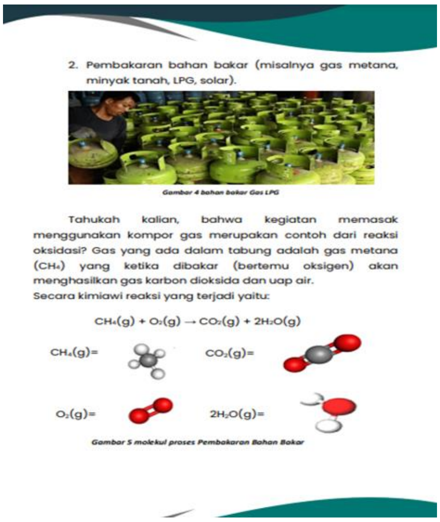


Figure 2 Display Module Contents

According to Johnstone (1991) in Philipp, Johnson, & Yezierski (2014), the levels of chemical representation used by experts in explaining chemical phenomena include:

a. Macroscopic representation

Macroscopic representation is the fundamental level that explains phenomena through direct observation of what happens to the human senses, such as the appearance of color changes, odors, and the formation of gases and precipitates in chemical reactions. The macroscopic representation presented in the module is shown in Figure 3.

2. Pembakaran bahan bakar (misalnya gas metana, minyak tanah, LPG, solar).

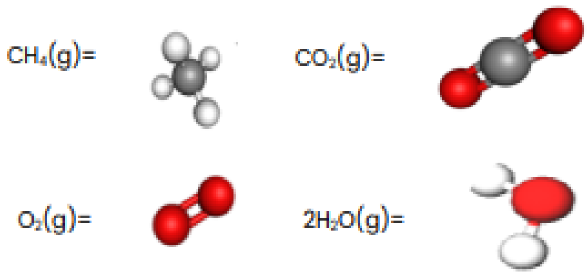
Gambar 4 bahan bakar Gas LPG

Tahukah kalian, bahwa kegiatan memasak menggunakan kompor gas merupakan contoh dari reaksi oksidasi? Gas yang ada dalam tabung adalah gas metana (CH_4) yang ketika dibakar (bertemu oksigen) akan menghasilkan gas karbon dioksida dan uap air.

Figure 3 Macroscopic Representation in Module

b. Submicroscopic Representation

Submicroscopic representation is a level of abstraction that explains macroscopic phenomena at the particle level. At the particle level, macroscopic phenomena are described in terms of atoms, molecules, or ions. The submicroscopic representation presented in the module is shown in Figure 4.



Gambar 5 molekul proses Pembakaran Bahan Bakar

Figure 4 Submicroscopic Representation in Module

c. Symbolic representation

Symbolic representation of macroscopic phenomena using chemical equations, mathematical equations, diagrams, reaction mechanisms, and analogies. The symbolic representation presented in the module is shown in Figure 5.

Secara kimiawi reaksi yang terjadi yaitu:

$$CH_4(g) + O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

Figure 5 Symbolic Representation in Module

The product development of this module is carried out through 4 stages of revision by supervisors, peer reviewers, material expert lecturers, media expert lecturers, reviewers, and students. the revision aims to evaluate the prototype by testing its feasibility by material, language, and graphics (Arianatasari, A.2018)

According to the material expert lecturer, the redox chemistry learning module based on multiple representations has excellent quality with an ideal percentage of 91.6%. Assessment of the feasibility aspect of the content gets excellent quality. This shows that the module can increase students' knowledge which is presented in detail, by developing science and technology and curriculum, displays phenomena that are by the surrounding environment, and has clear and varied questions. The assessment of the feasibility aspect of language getting excellent quality shows that the module uses clear language according to Indonesian language rules does not have multiple meanings, and is consistent in using notation/symbols to clarify the meaning of sentences. The assessment on the multiple representation aspect also got excellent quality. This shows that the multiple representation-based redox module presents the material with three scientific phenomena levels: macroscopic, submicroscopic, and symbolic. The representations presented are explicit and interrelated. This is by the research conducted. Kurniawan, R. A., & Fadhilah, R. (2018) in research on developing a multiple-representation-based chemistry learning module on the reaction rate material at SMA Panca Bhakti Pontianak, the results of material expert validation showed that the multiple-representation-based chemistry learning module was included in very valid criteria. With a value of 96.25%. Thus, the multiple-representation-based chemistry learning module can be used as a learning resource.

Based on the assessment of media expert lecturers, the overall module developed has excellent quality with an ideal percentage of 94.7%. The assessment on the presentation aspect gets excellent quality. This shows that the redox module based on multiple representations is presented coherently, systematically, and completely. The assessment of the visual aspect obtained excellent quality, indicating that the module has an attractive cover design and layout, presents clear images and supports the material's content, and uses proportional fonts. The assessment on the characteristic aspect of the module received excellent quality, indicating that the module was presented systematically by the curriculum and developments in science and technology and was easy to use to support learning outside of School. These results are also supported by research from Savitri, J., Firmansyah, R. A., & Wibowo, T. (2018) in research on the development of a chemical representation-based module on acid-base materials stating that the validation of media experts obtains an ideal of 92.5% with an excellent quality category which shows that the chemical representation-based chemistry learning module deserves to be tested on a small class scale to be reassessed by students as users of the learning module.

Based on the reviewer's assessment, the overall module developed has excellent quality with an ideal percentage of 81.25%. Assessment of the feasibility aspect of the content gets excellent quality. This shows that the redox module based on multiple representations can increase students' knowledge which is presented in detail by the development of science and technology and curriculum, displays phenomena that are by the surrounding environment, and there are clear and varied questions. The assessment on the feasibility aspect of language getting excellent quality shows that the redox module based on multiple representations uses clear language, according to Indonesian rules, does not have multiple meanings, and is consistent in the use of notation/symbols to clarify the meaning of sentences.

The assessment on the multiple representation aspect got excellent quality, indicating that the multiple representation-based redox module presents the material with three levels of scientific phenomena: macroscopic, submicroscopic, and symbolic. The representations presented are explicit and interrelated. The assessment on the presentation aspect obtained excellent quality, indicating that the redox module based on multiple representations was presented in a coherent, systematic, and complete manner. The assessment of the visual aspect obtained excellent quality, indicating that the redox module based on multiple representations has an attractive cover design and layout, presents clear images, supports the material's content, and uses proportional fonts. The assessment on the characteristic aspect of the module received excellent quality, indicating that the module was presented systematically by the curriculum and developments in science and technology and was easy to use to support learning at and outside of School. These results align with research conducted by Fahmi, T. N., & Fikroh, R. A. (2022) on developing a multi-representational charged module on hydrocarbon material for high school students who got an excellent results.

Students responded positively with the ideal percentage of 98.3%. The material aspect got a percentage of 98.6%, so it can be concluded that the redox module based on multiple representations was assessed by students as being able to support chemistry learning, presented clearly and systematically, and by school learning. The presentation and linguistic aspects each get a percentage of 100%, so it can be concluded that the multiple-representation-based redox module is assessed by students using language and sentences that are easy to understand. There are clear and appropriate instructions for using the module and pictures/illustrations to support the content. The design aspect gets a percentage of 98%, so it can be concluded that students assess the redox module based on multiple representations as having an attractive cover design and content. The practicality aspect gets a percentage of 92%, so it can be concluded that the redox module based on multiple representations is rated by students as easy to use without the teacher's help as a medium that supports learning outside or inside the School. The multiple representation aspect gets a percentage of 100%, so it can be concluded that the multiple representation-based redox module is assessed by students presenting content with three levels of scientific phenomena, namely macroscopic, submicroscopic, and symbolic on redox material. Presentation of an explicit representation so that it can assist students in learning the material.

The results of student responses from all aspects can be concluded that the redox module based on multiple representations gets a positive response in all aspects, which indicates that the redox module based on multiple representations is feasible and can be used as a learning resource for students, either with or without guidance from educators. These results align with research conducted by Adawiyah, R (2021) on the development of e-modules based on three levels of representation of chemical equilibrium material for high school students in grade xi to obtain very effective criteria from students.

Based on the study results, it can be concluded that the product of the redox module based on multiple representations developed has excellent quality and is suitable for use in learning which can help students understand the material presented in various representations. This result is supported by Julia, D (2016) in research on developing a module based on multiple representations of hydrolyzed salt material. The module based on multiple representations of hydrolyzed salt material developed is valid and suitable for use in learning at School. Another study conducted by Apriani, R.(2021) in the research on Development of Multiple Representation-Based Modules with the Assistance of Augmented Reality Technology to Help Students Understand the Concept of Chemical Bonds stated that the module developed was very valid in terms of the validity of the media, language, and material, so that it could be used in the learning process.

CONCLUSION

Based on the results of research and discussion, it can be concluded that:

1. The chemistry learning module product based on multiple representations of redox material is developed using a 4-D model (define, design, development, and disseminate), which is limited to the development stage. In the define stage, several stages are carried out: the analysis of material and curriculum needs. Several stages were carried out at the design stage: media selection, format selection, reference collection, instrument making, and initial module design. Meanwhile, at the development stage, instrument validation was carried out by one instrument expert lecturer, and product validation by three material expert lecturers, three media expert lecturers, two reviewers (chemistry educators), and 32 students responded. The product is a print-based learning module containing redox material for class X presented with various chemical representations, which are expected to make it easier for students to learn the material.
2. Based on the results of the quality assessment of the chemistry learning module based on multiple representations of redox material according to three material expert lecturers, it was obtained an average score of 33 from the ideal maximum score of 36 having excellent quality with an ideal percentage of 91.6% The results of the assessment of three lecturers media experts obtained an average score of 41.6 from the maximum ideal score of 44 having excellent quality with an ideal percentage of 94.7%. The assessment results of the two reviewers obtained an average score of 65 from the ideal maximum score of 80, having excellent quality with an ideal percentage of 81.25%. Based on the students' responses, a positive response was obtained by obtaining a score of 409 from a maximum score of 416 so that the ideal percentage was 98.3%. From all student assessments and responses, it can be concluded that the redox module based on multiple representations has excellent quality and can be used as appropriate teaching material by students.

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