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Chemical Learning Module Based on Multiple Representations of Redox Materials

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Abstract

This study aims to create and evaluate the effectiveness of a chemistry learning module based on various redox material representations. Research and development (R&D) is the methodology used in this research: using a 4D model. It consists of defining, designing, developing, and disseminating stages. The research was carried out until the development phase. The quality of the module was assessed by material experts, media experts, and reviewers (chemistry educators). The respondents are 32 students in first grade of Senior High School Science class. Quality assessment and student responses were made using a Likert and Guttman scale questionnaire sheet. The result shows that the percentage of objectives found by validating all aspects of the module's content by media, reviewers, and chemistry educators experts are 91.6%, 94.7%, and 81.25%, respectively, with excellent categories, and students responded positively to the module. The module is considered helpful as a learning media for redox topics.

Keywords: modules, multiple representations, redox, teaching materials

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1. Introduction

The result of interviews conducted with chemistry subject educators at Madrasah Aliyah eL-BAS Ciamis in September 2021 found that one of the problems experienced was the chemistry teaching materials. It was caused by the use of textbooks in the learning process. Moreover, students had difficulty learning independently, when students were not yet understood the materials in class. On the other hand, coupled with boarding schools that did not allow students to bring electronic devices; thus, it took extra work for students to find learning resources from various references. Lack of learning resources reduces student interest, especially in chemistry lessons that use many formulas, making them more challenging to understand. Besides, Ristiyani & Badriyah (2016) stated the results of his research that chemistry is one of the less interesting subjects because the material is abstract.

According to Nastiti et al. (2012), some complex concepts and phenomena are abstract and unobservable in chemistry. An essential chemistry feature is matter interaction at the macroscopic, submicroscopic, and symbolic levels. These three levels make most chemistry lessons difficult for students to understand (Sunyono, 2012). Therefore, efforts must be made to describe the abstract chemical substance more concretely (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 findings of Achmaliya and Kadaritna (2016) research 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.

The results of interviews with chemistry educators also found that oxidation-reduction (redox) reactions were one of the difficulties for students in the 10^{th} grade of Senior High School. This case is because students experience difficulties in solving problems involving chemical reactions and calculations chemistry, resulting in a low understanding of chemical concepts and a lack of interest in redox learning. Moreover, redox is one of the disciplines of chemistry and is characterized by specific symptoms; it also uses logical mathematical calculations and requires symbolic memory, understanding, application, and events that often occur in everyday life (Pratiwi et al., 2014). Besides, the teacher does not apply the redox concept in everyday life (Wanti & Yerimadesi, 2019).

In improving the learning process, teachers must make the studying process more innovative and optimal to encourage students to learn independently and guide learning in the classroom. Moreover, teachers should engage students in the learning process and use the media constructively. Media learning is required because the teaching and learning process is a communication process, delivering information from the introduction to the recipient (Munadi, 2013). Hence, teachers must be able to select and determine the learning material used (Tafonao, 2018).

According to Edgar Dale (1969), one way to define teaching materials is as tools for assisting and facilitating learning. Added by Sitepu (2014) stated that teaching materials include everything that can be used to help everyone learn and demonstrate their abilities. Karwono & Mularsih (2017). Teachers and students can both benefit from the resources while learning. With this material, the impact of learning on students also increases (Firaihanil, 2018).

A module is one of the instructional tools employed during the learning process, a form of teaching material designed to encourage independent learning in students (Asyhar, 2012). This module allows students to test themselves through the exercises (Daryanto, 2014). Modules play an essential role in learning. Students can develop their capacity for independent learning. Students can test their skills through the tasks supplied in the module, and they can describe how they study according to their talents and interests (Mulyasa et al., 2019).

Based on the facts of the problem found, the researcher intends to develop a chemistry learning module based on multiple representations. Permadi (2013) states that students understand the material is based not only on one representation alone but also on many representations, which can be obtained from the experiment or any books available. In other words, students are required to master various representations such as experiments, graphics, conceptual/oral descriptions, formulas, as well as pictures or diagrams at the same time as students learn chemical material.

Furthermore, research conducted by Nurpratami et al. (2015) on speed material reactions using based teaching materials multiple chemical representations, active ingredient multiple chemical representations valid with the right value interpretation very feasible in the 80-89% range. The test results of teaching materials got a good response of 80%, a response which stated that it was 17.78% and stated less than 2.22%. Therefore, multiple active ingredients' chemical representation of the material reaction rate categorized as good can be used as a learning resource. This data is also supported by Ramdhani et al. (2020) research on the effectiveness of multiple representations integrated electronic modules on chemical bonding materials. The study's findings demonstrate a considerable difference between the experimental and control class' performance of the integrated electronic module with multiple representations of high school chemistry learning in bonding materials. This chemistry shows that the module is effective for use in the learning process.

Using the justification provided, the researcher aims to create a chemical learning module based on multiple representations of redox material at Madrasah Aliyah eL-BAS Ciamis. Redox material for 10^{th} grade is presented in this module. It includes three levels of chemical representation, macroscopic, submicroscopic, and symbolic which is intended to aid students in their study. Teaching materials based on multiple representations can make it easier to understand abstract scientific concepts (Sianturi et al., 2019). Learning with multiple representation approaches can bridge the process of students' understanding of chemical concepts (Wiyarsi et al., 2018).

2. Research Method

This research used research and development (R&D) with a 4D development research model. According to Sukmadinata (2013), development research is a technique for creating or enhancing new products. In addition, this study uses a 4D research model developed by Thiagarajan (1974) covering defining, planning (designing), developing, and disseminating, which is only enforced until the development stage. There are three stages of The 4D Model.

2.1. Define Stage

An initial analysis is carried out in the define stage to determine the problems faced. This stage is carried out to describe everything needed in the field so that researchers can find out the problems that will be faced and get the solutions (Karim et al., 2022). To support this research, several stages are carried out a needs analysis is conducted by conducting interviews with chemistry educators and 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 10^{th} grade.

2.2. 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 including the selection of the format using the format according to the National Education Standards Agency (BSNP in Indonesian) and the book center in the form of the module size used was B5. The selected font was Poppins. The reference material was collected from various valid sources, such as a senior high school chemistry book. Moreover, the official website creates data-gathering tools related to the National Education Criteria Agency module quality criteria. Therefore, 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.

2.3. Develop Stage

The development stage is an activity that includes the formation of product designs and repeated product verification tests until the product is produced as specified. Expert validation and development trials are the two actions that Thiagarajan separates the development stage into (Rhamdany & Arifin, 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 one (draft two) based on the comments and suggestions of supervisors and peer reviewers. The 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 one (draft two) to material experts and media experts to produce comments and recommendations for revisions to the product and production revision two (draft three). The inputs, the chemistry educator, and student responses then validated the suggested results to produce revision three (draft four).

The qualitative data from the validated results provide input and recommendations for module enhancement. The quality assessment results are quantitative data obtained from scores from the Likert scale. Likert scale can be seen in Table 1.

Table 1. Table of Likers Scale

No	Information	Score
1.	Least	1
2.	Less	2
3.	Good	3
4.	Excellent	4

Sugiyono (2018) claims that the Likert scale evaluates a person's or group's attitudes, views, and perceptions. 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 tool for getting affirmative responses from respondents. There are only two intervals, such as "agree-disagree,"; "Yes or no,"; "Right and wrong,"; "Positive and negative,"; "Never," and other. The measurement scale can produce multiple-choice questions and checklist-style, with answers given a maximum (agree) 1 and a minimum (disagree) 0 (Sugiyono, 2014). Data analysis techniques in writing this development are as follows:

2.3.1. Product Validation

Product validation data contains suggestions and input from material experts, media experts, peer reviewers (Chemical Education students), and reviewers (high school/MA chemistry teachers). This data is used as a guide for improving the module based on multiple representations.

2.3.2. Product Quality Assessment Data

Product quality assessment data from material experts, media experts, and reviewers (Senior high school/MA chemistry teachers) were analyzed using the following steps:

The First is to change the results of the product quality assessment product formed by letters (qualitative data) into scores (quantitative data) with the provisions in Table 2.

Table 2. Table of Scoring Rules

No	Information	Score
1.	Least	1
2.	Less	2
3.	Good	3
4.	Excellent	4

The second is calculating the average score from the assessment of the material expert, media expert, reviewer (Senior high school/MA chemistry teacher), and student responses for all aspects of the assessment with the following formula (Widiyoko, 2009).

$$\bar{X} = \frac{\Sigma x}{N}$$

$\bar{X}$ = average score
Σx = Total score
N = Number of ratings

The third is converting the average score into a quality score with ideal scoring criteria. The reference for changing the score to the value of the provisions can be seen in Table 3 below (Mardapi, 2018).

Table 3. Table of Ideal Rating Criteria

No	Score Range	Category
1.	$x \geq \bar{x} + SBi$	Excellent
2.	$\bar{x} + SBi > x \geq \bar{x}$	Good
3.	$\bar{x} > x > \bar{x} - SBi$	Less
4.	$x < \bar{x} - SBi$	Least

Information:
x = actual score
$\bar{x}$ = average number of ideal scores
= $\frac{1}{2}$ (ideal maximum score + ideal minimum score)
SBi = standard deviation of ideal score
= $(\frac{1}{2})(\frac{1}{3})$ (ideal maximum score-ideal minimum score)
Ideal maximum score = Σ criteria item × highest score
Ideal minimum score = Σ criteria item × lowest score

The last one is calculating the percentage of the ideal quality of the chemistry module based on multiple representations for all aspects of the assessment with the formula :

% Overall ideal =

$$\frac{\textit{the average score of all aspects}}{\textit{the highest score ideal for all aspects}} \text{ x } 100\%$$

% The ideal of every aspect =

$$\frac{\textit{the average score of all aspects}}{\textit{the highest score ideal for all aspects}} \text{ x } 100\%$$

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

3. Result and Discussion

This development research produced a product in the form of a chemistry learning module as its end product. The produced module was based on multiple representations of redox material for senior high school in 10^{th} grade. The developed product was a printed module using Microsoft Word and Corel Draw software.

The material in this product was developed according to core competence (KI) and basic competence (KD) in the 2013 curriculum. This module product contains oxidation-reduction reaction chemistry (Redox), which is presented with various representations: macroscopic, submicroscopic, and symbolic. The display of the contents of the module can be seen in Figure 1.

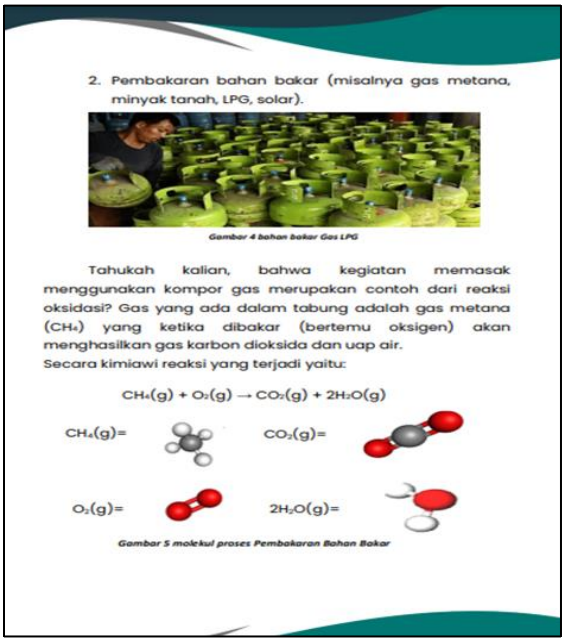

Figure 1. Display Module Content

According to Johnstone (1991) in Philipp et al. (2014), the levels of chemical representation used by experts in explaining chemical phenomena include macroscopic, submicroscopic, and symbolic representations.

On the fundamental level macroscopic representation 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.

Submicroscopic representation is a level of abstraction that explains macroscopic phenomena at the particle level. At the particle level, macroscopic phenomena are described as atoms, molecules, or ions.

Symbolic phenomena can be represented using chemical equations, mathematical equations, graphs, reaction mechanisms, and analogies.

The macroscopic, submicroscopic, and symbolic representation presented in the module is shown in Figure 2.

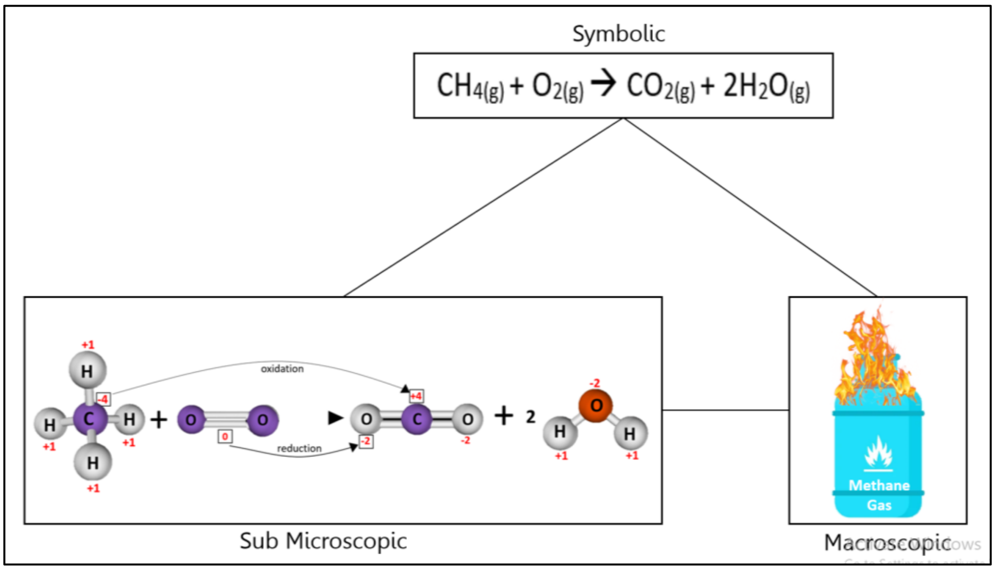

Figure 2. The Macroscopic, Submicroscopic, and Symbolic Representation

In Figure 2, three chemical representations are presented according to the module's characteristics which are macroscopic, submicroscopic, and symbolic representations. The macroscopic representation is presented as an image of Liquefied Petroleum Gas (LPG) often encountered daily. Submicroscopic representation is presented as pictures of molecules in the fuel combustion process. An oxidation reaction is a molecule that lacks hydrogen or adds oxygen and whose oxidation number increases with the loss of electrons. Meanwhile, a molecule that loses oxygen, gains electrons and lowers the oxidation number is called a reduction reaction. Symbolic representation is presented as reaction formulas that occur in the fuel combustion process.

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

3.1. Material Expert

Three material experts validated by completing a quality assessment form, which was transformed into quantitative data and tabulated and examined to ascertain product quality. Also, aspects of content feasibility, language feasibility, and chemical representation were validated. The table of material expert validation results can be seen in Table 4.

Table 4. Table of 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

According to the material expert, the redox chemistry learning module based on multiple representations had excellent quality, with an ideal percentage of 91.6%. This data shows that modules based on multiple representations of redox material had the material following the national curriculum, complete, structured, and easy to understand. Meanwhile, the assessment of the feasibility aspect of the content gots excellent quality. This finding shows that the module could increase students' knowledge; it was presented in detail by developing science and technology curriculum models, displaying phenomena in the surrounding environment, and having clear and varied questions. The assessment of the feasibility aspect of language getting excellent quality showed that the module used clear language according to Indonesian language rules; it did not have multiple meanings and consistently used notation/symbols to clarify the meaning of sentences. The assessment on the multiple representation aspect also got excellent quality. On the side, this data shows that the multiple representation-based redox module presents the material with three scientific phenomena levels: macroscopic, submicroscopic, and symbolic. Thus, the representations presented were explicit and interrelated.

Furthermore, this finding was supported by the research conducted by Kurniawan & Fadhilah (2018) on the development of a multiple-representation-based chemistry learning module for the reaction rate material at a senior high school in Panca Bhakti of Pontianak. According to the material expert validation results, the multiple-representation-based chemistry learning module met very valid criteria; it scored 96.25%. Consequently, the multiple-representation-based chemistry learning module could be a learning tool.

3.2. Media Expert

Three media experts were asked to validate the student's answers by completing a quality assessment form, which was then transformed into quantitative data and tabulated and evaluated to ascertain product quality. The aspect validated were presentations, graphics, and module characteristics. The results of media expert validation can be seen in Table 5.

Table 5. The Table of 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

Based on the assessment of media expert lecturers, the overall module developed had excellent quality, with an ideal percentage of 94.7%. The assessment of the presentation aspect got excellent quality. This data showed that the redox module based on multiple representations was presented coherently, systematically, and completely. The assessment of the visual aspect obtained excellent quality, indicating that the module had an attractive cover design and layout, presented clear images and supported the material's content, and used 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 were also supported by research from Savitri et al. (2018) in research on the development of a chemical representation-based module on acid-base materials stating that the validation of media experts obtained an idea of 92.5% with an excellent quality category which showed 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.

3.3. 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. Meanwhile, the aspects validated were content feasibility, language feasibility, presentation aspects, visual aspects, module characteristics aspects, and multiple presentation aspects. Thus, the table of validation results for chemistry educators can be seen in Table 6.

Table 6. Table of Results Validation by Chemistry Educators

Aspect	Ideal Percentage (%)	Category
Content Eligibility	75%	Excellent
Language Eligibility	79%	Excellent
Presentation	95%	Excellent
Graphic	100%	Excellent
Module Characteristic	80%	Excellent
Multiple Representations	81,25%	Excellent
Total	81,25%	Excellent

Based on the reviewer's assessment, the overall module developed had excellent quality, with an ideal percentage of 81.25%. Assessment of the feasibility aspect of the content got excellent quality. This data showed that the redox module based on multiple representations could increase students' knowledge which was presented in detail by the development of science and technology and curriculum, displays phenomena in the surrounding environment, and there were clear and varied questions. Besides, the assessment on the feasibility aspect of language getting excellent quality showed that the redox module based on multiple representations used clear language because it followed the Indonesian rules, did not have multiple meanings, and consistently used notation/symbols to clarify the meaning of sentences.

On the other hand, 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 were explicit and interrelated. The assessment on the presentation aspect obtained excellent quality, indicating that the redox module based on multiple representations was presented coherently, systematically, and completely. The assessment of the visual aspect obtained excellent quality, indicating that the redox module based on multiple representations had an attractive cover design and layout, presented clear images, supported the material's content, and used 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 & Fikroh (2022) on developing a multi-representational charged module on hydrocarbon material for high school students who got excellent results.

3.4. Student Responses

In the High School Science Class, 32 students in 10th grade 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 results of student responses can be seen in Table 7.

Table 7. Table of Result Student Responses

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

In Table 7, students had an ideal percentage of 98.3%, meaning they responded positively. Also, the material aspect got a percentage of 98.6%. Consequently, students could use the redox module based on multiple representations to support the chemistry learning process because it was presented clearly and systematically in school. Besides, the presentation and linguistic aspects each got a percentage of 100%; consequently, the multiple-representation-based redox module was assessed by students using language and sentences that were easy to understand. There were clear and appropriate instructions for using the module and pictures/illustrations to support the content.

Conversely, the design aspect got a percentage of 98%. As a result, students assessed the redox module based on multiple representations as having an attractive cover design and content. One more time, the practicality aspect got a percentage of 92%. Hence, students rate the redox module based on multiple representations as easy to use without the teacher's help as a medium that supports learning outside or inside the school. Moreover, the multiple representation aspect got a percentage of 100%. Therefore, the multiple representation-based redox module was assessed by students presenting content with three levels of scientific phenomena: macroscopic, submicroscopic, and symbolic redox material. In addition, the presentation of an explicit representation can assist students in learning the material.

The results of student responses from all aspects showed that the redox module based on multiple representations got a positive response in all aspects. It was indicated that the redox module based on multiple representations was feasible, and it was a resource for students to support their chemistry learning process without guidance from educators. These findings aligned with research conducted by Adawiyah et al. (2021), which explored the development of e-modules based on three levers of representation of chemical equilibrium material for high school students in 11th grade of senior high school to obtain very effective criteria from students.

According to the study's findings, the product of the redox module based on multiple representations has excellent quality. It can be used in the learning process to help students understand the material presented in various representations. This result is supported by Julia et al. (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 was valid and suitable for use in learning at school. Another study conducted by Apriani et al. (2021) in the research 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.

4. Conclusion

Based on the findings of the evaluation of the chemistry learning's quality module based on multiple representations of redox material according to three material expert lecturers, it gained 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 gained 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 gained 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 student's responses, a positive response was obtained by obtaining a score of 409 from a maximum score of 416, so the ideal percentage was 98.3%. From all student assessments and responses, the redox module based on multiple representations has excellent quality and can be used as appropriate teaching material for students.

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