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***Corresponding author**

mawardianwar@fmipa.unp.ac.id

DEVELOPMENT OF TEACHING MATERIALS TO SUPPORT THE MERDEKA CURRICULUM IN REDOX REACTIONS AND ELECTROCHEMISTRY FOR PHASE F SENIOR HIGH SCHOOL**Nalisha Jasmine^a, Mawardi Mawardi^{a*}, Okta Suryani^a, Reza Akmar^a**^aChemistry Departement, Universitas Negeri Padang, Padang, Indonesia, 25132**Abstract**

This study evaluates the development of multi-representational teaching materials for redox and electrochemistry to support the Merdeka Curriculum in Phase F senior high school. Educational Design Research (EDR) was the chosen methodology, and the study involved three university chemistry lecturers, two chemistry teachers, and nine students. Data collection was carried out using validity and practicality questionnaires. The results revealed that the average construct validity score of 0.87 and the average content validity score of 0.86 classified the materials as valid. Furthermore, the practicality assessment showed that this teaching material received a high practicality score of 97% from teachers and 92% from students, indicating ease of application in learning. In conclusion, the teaching materials developed for redox and electrochemistry lessons, incorporating multiple chemical representations, were both valid and highly practical, supporting the goals of the Merdeka Curriculum in fostering deeper student understanding.

Keywords: Electrochemistry, Merdeka Curriculum, Redox Reaction, Teaching Material 10.24815/jcd.v12i2.41981Attribution-NonCommercial-ShareAlike 4.0 International
(CC BY-NC-SA 4.0)**INTRODUCTION**

Learning loss among students is one of the impacts of the Covid-19 pandemic. This pandemic has caused Indonesia to experience a learning crisis [1], [2]. Indonesian students face various learning challenges, including difficulty with basic reading comprehension and fundamental mathematical concepts [3]. In response to this situation, the Ministry of Education, Culture, Research, and Technology of the Indonesian government has made efforts to recover by introducing a new curriculum called the Merdeka Curriculum [4].

The Merdeka Curriculum is designed to offer various learning experiences, giving students enough time to understand ideas and achieve their goals [5]. The Merdeka Curriculum also helps students prepare for the challenges of today's world, where skills like thinking critically and solving problems are important [6]. It aims to make students more creative, innovative, and good at communicating and working with others, both in their studies and daily life [7].

Like previous curricula, the Merdeka Curriculum requires teachers to play the role of knowledge providers and create a lively classroom atmosphere. Additionally, teachers are expected to actively engage in creating a student-centered learning process [8]. Therefore, teachers' pedagogical skills are also expected to foster a more creative and innovative learning environment so that they are not the sole source of knowledge in the classroom. [9]. To achieve this, teachers are given the flexibility to choose various teaching materials that support the learning process, tailored to the needs and interests of the students. [10]. One such resource that can support learning in the Merdeka Curriculum is teaching materials [11].

Teaching materials play a crucial role in preparing students for the era of Revolution 4.0 and Civilization 5.0 [12].

The purpose of developing teaching materials is to provide content that matches the current curriculum while considering the characteristics and social environment of the students. These materials can be either written or non-written [1]. Examples of teaching materials include audio resources, audiovisual materials like educational videos, and printed resources such as handouts, textbooks, modules, student activity sheets, photos, images, and diagrams [13]. The function of textbooks is to focus on the needs of students [14]. They serve as learning tools, sources of information, and practice materials to help students master specific subjects [15].

Chemistry is one of the subjects that students must study at senior high school. Redox reactions and electrochemistry are topics included in this subject [16]. These topics involve concrete concepts, mathematical logic, and the need to understand symbols and their application in daily life. However, the complexity of these topics often challenges students, making them difficult to learn. Specific difficulties include natural phenomena that are not always related to redox reactions, the complicated workings of electrochemical cells, and the precise calculations required for applying redox reactions and electrochemistry [17].

To help students understand chemistry, especially redox reactions and electrochemistry, it's essential to grasp three levels of chemical representation: macroscopic, submicroscopic, and symbolic [18]. These levels are interconnected and each helps students develop mental models, which are internal

ways of thinking about chemical concepts [19]. The macroscopic level involves observable phenomena, such as colour changes or gas bubbles. The submicroscopic level focuses on atomic and molecular processes that aren't visible directly but explain how reactions occur. The symbolic level uses chemical formulas and symbols to represent substances and reactions [20]. Multiple representations of chemistry help students visualize the process, while molecular models clearly understand how atoms are arranged and bonded, preventing potential misconceptions [21]. By using these different tools, students can apply their mental models more effectively [22]. Various representations make it easier for students to understand and solve complex chemistry problems [23]. Although the submicroscopic level is often less emphasized, it is crucial for creating accurate mental models and understanding concepts in chemistry [24].

Based on interviews and questionnaires conducted at SMA Negeri 7 Padang, SMA Negeri 8 Padang, and SMA Pertiwi Padang, it was found that the available textbooks lack multi-representational content. Teachers at these schools recognized the need for more comprehensive and detailed supplementary materials that include various representations of chemistry. Therefore, it is essential to innovate reader-friendly teaching materials and incorporate visually appealing illustrations to encourage students to explore the subject matter further.

The developed teaching materials address these limitations and help students understand concepts through multi-representational content. Designed to support the Merdeka Curriculum for phase F senior high school, these materials are engaging and tailored to meet students' needs, promoting independent learning and a student-centered approach. This research, therefore, focuses on developing teaching materials titled "Development of Teaching Materials to Support the Merdeka Curriculum in Redox Reactions and Electrochemistry for Phase F Senior High School."

METHOD

This research uses a development research method with an educational design approach, known as Educational Design Research (EDR), carried out through several stages, which refer to the Plomp (2010) model of development. In the Plomp model, there are three main stages: the preliminary research stage, the prototyping stage, and the assessment phase [26].

The preliminary stage involved needs and context analyses to assess the demand for specialized teaching materials on redox and electrochemistry for the Merdeka Curriculum. Input was collected from chemistry teachers and students. Context analysis helped evaluate learning objectives, and we reviewed relevant literature to support the research. A conceptual framework was then developed, linking identified needs with the literature to generate a product solution. Following this, in the prototyping

phase, the teaching materials were designed and refined through a formative evaluation process involving self-evaluation, expert review, one-to-one evaluation, and small group evaluation.

After the preliminary research stage, the teaching materials were designed. This development or prototype stage follows a process that assists in developing and refining the product. The process involves formative evaluation, which consists of four stages: self-evaluation, expert review, one-to-one evaluation, and small group evaluation, as illustrated in the figure below.

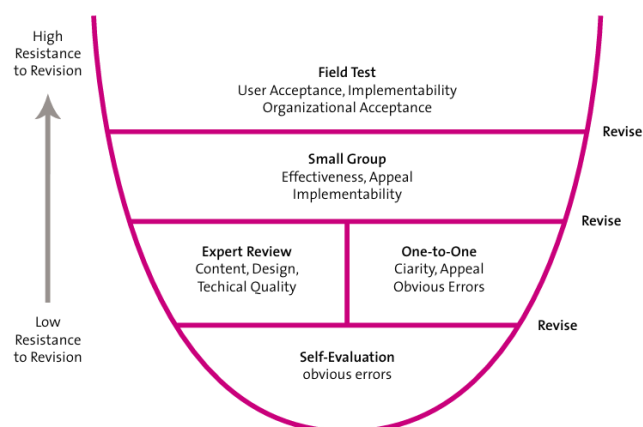


Figure 1. Layers of Formative Evaluation

The tools used for data collection in this study include measures of validity and measures of practicality. In analyzing the validity sheets completed by the validators, Aiken's V scale is used, which refers to Boslaugh's categorical judgements with modifications [27]. The responses required from the validators involve evaluating the statements on the validity sheet, which is provided as a questionnaire or survey. At the end, the validators are given an opportunity to determine the results of the evaluation they have provided. The validators' assessments of each statement are analyzed using Aiken's V formula, as shown in the equations below.

$$V = \frac{\sum s}{n(c - 1)}$$

$$s = r - I_0$$

Where:

V : Aiken's V scale

s : score from the validator minus the lowest score in the category applied

r : score/category selected by the validator

I_0 : lowest validity rating

n : number of validators

c : highest validity rating

Since the items used involve five validators and five selection categories, the scale used for Aiken's validity index is as shown in the following table:

Table 1. Aiken's Validity Index Categories for Five Validators

Aiken's V Index	Validity Category
$V \geq 0.80$	Valid
$V < 0.80$	Invalid

The technique used to analyze practical data is based on the following formula:

$$\text{Practicality Score} = \frac{\text{total score obtained}}{\text{highest possible score}} \times 100\%$$

The percentage score obtained is then grouped into several criteria as follows:

Table 1. Category of Practicality Level

Values	Practicality Category
86% - 100%	Very Practical
76% - 85%	Practical
60% - 75%	Quite Practical
55% - 59%	Less Practical
$\leq 54\%$	Not Practical

RESULTS AND DISCUSSION

Preliminary Research

The needs and context analysis, gathered via student questionnaires and teacher interviews, highlighted a critical shortage in resources, especially for multi-level chemical representations. Current materials lacked integration of the macroscopic, submicroscopic, and symbolic levels of chemical representation. These materials lacked the inclusion of three levels of chemical representation. This suggests that students require additional reference materials or other teaching resources to further support their chemistry learning at school.

One of the topics studied in chemistry is redox and electrochemistry. Redox and electrochemistry reactions include balancing redox equations, the principles of voltaic cells, the use of voltaic cells, factors affecting corrosion, ways to prevent corrosion, electrolysis, and Faraday's law. Redox and electrochemistry involve the phenomenon of electron transfer, which requires an understanding of the three levels of chemical representation (macroscopic, submicroscopic, and symbolic). These levels are crucial for developing accurate mental models in students. However, the teaching materials for the Merdeka Curriculum available in schools do not yet include these three levels of chemical representation.

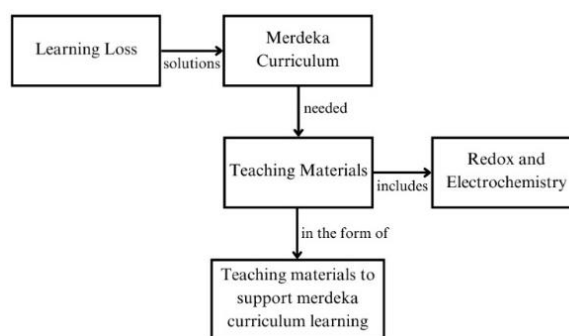
Based on the needs analysis above, teaching materials on redox and electrochemistry were developed, incorporating content that includes the three levels of chemical representation to support the Merdeka Curriculum in schools. In the context analysis, an analysis was conducted on the curriculum used in schools [28]. At this stage, the analysis focused on the competencies that students must master, namely the

Chemistry Learning Outcomes for phase F, which were then broken down into the Learning Objectives for redox and electrochemistry. This was done to ensure that the developed teaching materials were systematically structured in line with the learning objectives that had been formulated.

The literature review stage aims to connect the problems faced by teachers and students in the learning process of the Merdeka Curriculum, aiming to identify solutions through the analysis of scientific articles from various journals. In light of these issues, it is essential to design a product, namely the development of teaching materials to support the learning of the Merdeka Curriculum on the topic of redox and electrochemistry in phase F for senior high school, using the Plomp development model through validity and practicality testing.

In the literature review stage of this research, several supporting references were gathered, including those on teaching materials, the Merdeka Curriculum, and redox and electrochemistry. The content on redox and electrochemistry in the developed teaching materials is sourced from various textbooks, which are General Chemistry by Ebbing & Gammon (2017), Chemistry by Chang (2010), Chemistry The Molecular Science by Moore (2011), and many others.

Finally, a conceptual framework was developed, synthesizing the needs analysis, context analysis, and literature review. This framework helped identify the core problems and guide the solutions for the research, ultimately supporting the development of the teaching materials. The results of this framework are illustrated in the following figure.

**Figure 2.** Conceptual Framework

Development or Prototyping Phase Prototype I

Prototype I is the prototype developed from the initial design following the preliminary research. The result of Prototype I is teaching material to support the Merdeka Curriculum. The components included in the developed teaching material are cover, preface, table of contents, book usage instructions, learning outcomes, concept maps, chapter cover, sample questions and solutions, exercises, summary, end-of-chapter exercises, activities, reflections, bibliography,

glossary, and index. The following are some of the components contained in the developed teaching materials.

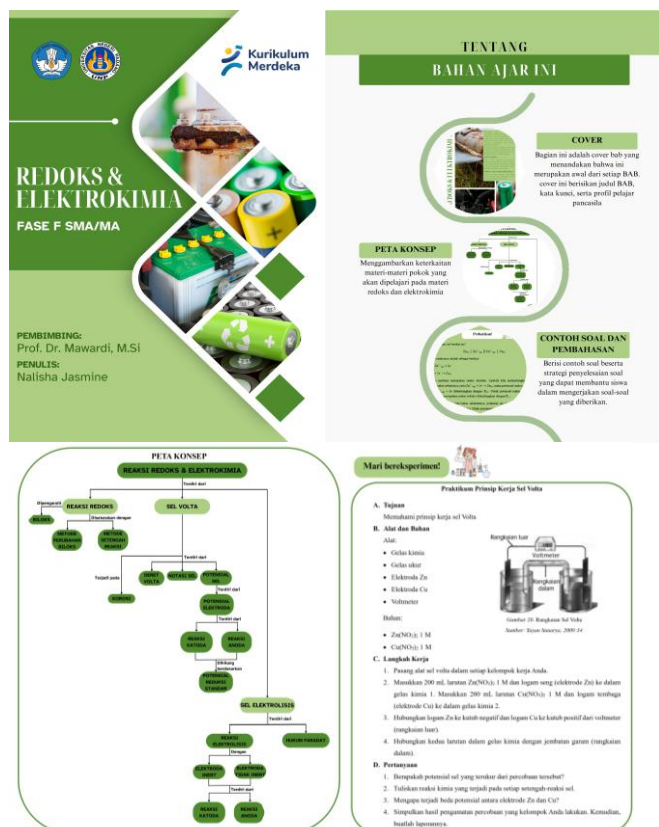


Figure 3. Cover of the module, book usage instruction, conceptual maps, and, lab activities

Prototype II

Prototype II is the result of revising Prototype I. After developing the teaching material in the form of Prototype I, a formative evaluation was conducted, including a self-evaluation using a checklist questionnaire. At this stage, the researcher reviewed and re-evaluated the completeness of the teaching material components. Based on the self-evaluation results, one missing component was identified: the comprehension test. Therefore, the researcher revised the teaching material by adding this missing component, the comprehension test. At this stage, the researcher conducted a thorough review and self-evaluation of the teaching materials to ensure their completeness and effectiveness. This process revealed the absence of a critical component: the comprehension test, which is essential for assessing students' understanding of the material. Recognizing its importance, the researcher promptly addressed this gap by revising the teaching materials to include a well-designed comprehension test. This addition not only enhances the overall structure and functionality of the materials but also provides a reliable tool for evaluating learners' grasp of the content, thereby improving the instructional quality and learning outcomes. The comprehension test can be seen in Figure 4.

UJI PEMAHAMAN

- Pada sel volta, elektron mengalir dari...
 - Potensial rendah ke potensial tinggi
 - Kutub positif ke kutub negatif
 - Anode ke katode melalui sirkuit eksternal
 - Setengah sel reduksi ke setengah sel oksidasi
 - Anode ke katode melalui jembatan garam
- Perhatikan potensial sel berikut.

A A^{2+} B^{2+} B $E^\circ = 3,5$ V	D. 4,7 V
C C^{2+} D^{2+} D $E^\circ = 1,2$ V	E. 4,05 V
C C^{2+} B^{2+} B $E^\circ = 1,75$ V	

 Potensial sel: A | A^{2+} || D^{2+} | D adalah...

A. 2,95 V	D. 4,7 V
B. 6,45 V	E. 4,05 V
C. 0,35 V	
- Perkaratan besi pada suhu kamar dipengaruhi oleh adanya...

A. Oksigen saja	D. Air dan argon
B. Air dan nitrogen	E. Air saja
C. Oksigen dan air	
- Pada elektrolisis larutan perak nitrat dengan menggunakan elektrode karbon, persamaan reaksi yang terjadi pada anode adalah...

A. $Ag^+(aq) + e^- \rightarrow Ag(s)$	
B. $2H_2O(l) + 2e^- \rightarrow 2OH^-(aq) + H_2(g)$	
C. $2H_2O(l) \rightarrow 4H^+(aq) + O_2(g) + 4e^-$	
D. $Ag(s) \rightarrow Ag^+(aq) + e^-$	
E. $2NO_3^-(aq) \rightarrow 2NO_2(g) + O_2(g) + 2e^-$	
- Pada elektrolisis, jumlah arus listrik pada waktu tertentu dapat mengendapkan 0,01 mol Ag. Jika jumlah arus listrik dan waktu yang sama dialirkan ke dalam larutan Cu^{2+} maka logam Cu yang diendapkan sebanyak...

A. 0,001 mol	D. 0,02 mol
B. 0,005 mol	E. 0,10 mol

Figure 4. Comprehension Test

Prototype III

Prototype III is the result of revising Prototype II. At this stage, formative evaluations were conducted. This included an expert review by five validators, which comprised three chemistry lecturers from UNP and two chemistry teachers from SMA Negeri 8 Padang, as well as a one-to-one evaluation through interviews with three students. The validation process involved two types of questionnaires. The first was the construct validation questionnaire, which included 16 statements and was divided into four aspects: content components, presentation components, language components, and graphical components. The second was the content validation questionnaire, which assessed the alignment of the teaching material with the Merdeka Curriculum. The content validation received a score of 0.86, indicating it is valid and the construct validation received an average score of 0.87, which is also classified as valid. The results of the construct validation are shown in Figure 8. The following are some of the revisions made after the validation stage.



Figure 5. Chapter cover before and after revision

The text on the chapter cover has been darkened to ensure it is readable. The choice of font color in a teaching material design should be considered to ensure it is easy to read.

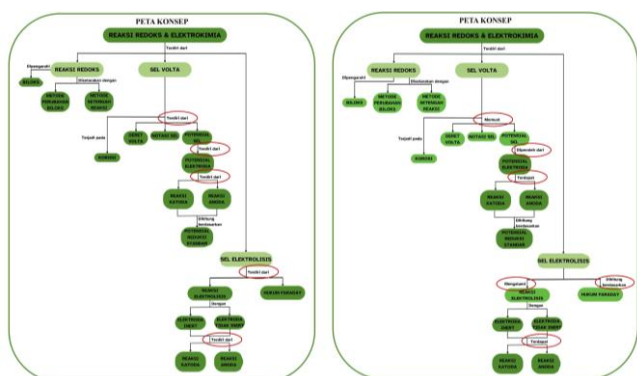


Figure 6. Conceptual map before and after revision

In the developed concept map, some words connecting the main concepts and their subordinates needed to be more appropriate. Therefore, several connecting words were revised to provide more specific explanations that better illustrated the relationships between the concepts.

A. Soal Pilihan Ganda 1. Perhatikan persamaan reaksi redoks berikut. $\text{aMnO}_4^- + 16\text{H}^+ + 5\text{C}_2\text{O}_4^{2-} \rightarrow \text{aMn}^{2+} + 8\text{H}_2\text{O} + 10\text{CO}_2$ a dan b berturut-turut adalah... A. 2 dan 3 B. 2 dan 2 C. 2 dan 5 D. 3 dan 5 E. 2, 4, dan 5 B. Pilihan Ganda Kompleks 1. Perhatikan reaksi redoks berikut. $2\text{NaCl} + 2\text{H}_2\text{O} \rightarrow \text{H}_2 + \text{Cl}_2 + 2\text{NaOH}$ Pernyataan yang benar berdasarkan reaksi di atas adalah... ☐ NaCl mengalami reduksi ☐ NaCl mengalami oksidasi ☐ H₂O mengalami oksidasi ☐ H₂O berperan sebagai reduktor ☐ NaCl berperan sebagai reduktor	A. Soal Pilihan Ganda 2. $\text{Ag}^+ [\text{Ag}]/[\text{Cu}]/\text{Cu}^{2+}$ 4. Rata-rata harga E° untuk Zn dan Cu yaitu: $\text{Zn}^{2+} + 2\text{e}^- \rightarrow \text{Zn} \quad E^\circ = -0,76 \text{ V}$ $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu} \quad E^\circ = +0,34 \text{ V}$ Potensial sel Volta dengan elektrode Zn dan Cu yang berjalan spontan adalah... A. 0,34 V B. 1,10 V A. Soal Pilihan Ganda 6. Perhatikan persamaan reaksi redoks berikut. $\text{aMnO}_4^- + 16\text{H}^+ + 5\text{C}_2\text{O}_4^{2-} \rightarrow \text{aMn}^{2+} + 8\text{H}_2\text{O} + 10\text{CO}_2$ a dan b berturut-turut adalah... A. 2 dan 3 B. 2 dan 2 C. 2 dan 5 D. 3 dan 5 E. 2, 4, dan 5 B. Pilihan Ganda Kompleks 1. Perhatikan reaksi redoks berikut. $2\text{NaCl} + 2\text{H}_2\text{O} \rightarrow \text{H}_2 + \text{Cl}_2 + 2\text{NaOH}$ Pernyataan yang benar berdasarkan reaksi di atas adalah... ☐ NaCl mengalami reduksi ☐ NaCl mengalami oksidasi ☐ H₂O mengalami oksidasi ☐ H₂O berperan sebagai reduktor
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Figure 7. End-of-chapter exercises before and after revision

For the end-of-chapter exercises, clear instructions need to be provided on what students should do. This aims to make it easier for them to complete the end-of-chapter exercises. The following is a diagram of the construct validity results of the teaching materials by five validators.

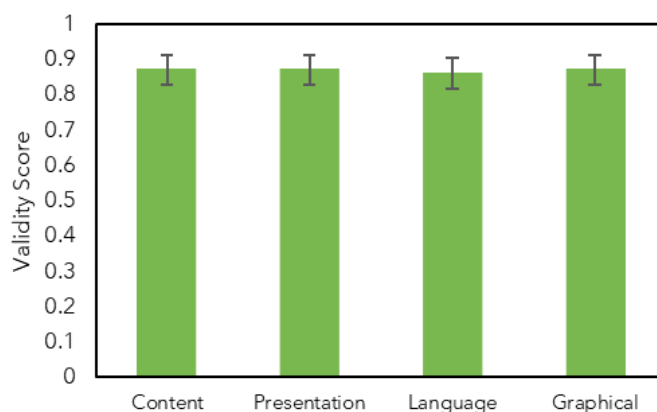


Figure 8. Construct validity score

Figure 8 displays the teaching material's validity scores of four components—Content, Presentation, Language, and Graphical. Each component scored between 0.8 and 0.9, indicating high validity. The error bars show a small margin of variability, suggesting consistent evaluations across reviewers. Among the components, the Content and Language sections appear slightly higher, reflecting robust design and quality in these areas. The scores demonstrate an overall strong alignment with validity criteria, with minor variations suggesting room for refinement, particularly in Presentation and Graphical elements.

After experts evaluated prototype II through the expert review stage, a one-on-one evaluation was conducted by interviewing three phase F students from SMAN 8 Padang. This stage aimed to gather student feedback on the teaching materials that has been developed. The one-on-one evaluation results revealed that the textbook's overall appearance is appealing, with a well-designed cover and comprehensive, detailed content. The textbook includes a variety of activities aligned with the "Projek Pelajar Pancasila", as well as a diverse range of exercise questions that meet the demands of the Merdeka Curriculum. In addition to written content, the textbook features images that enhance students' understanding of the material. It also contains various projects aimed at improving students' skills and creativity.

Prototype IV

After conducting the validity test, a practicality test was carried out with both teachers and students. The practicality test was conducted to determine whether the developed product is easy and practical to use [32]. The practicality test results were obtained from a small group test conducted with nine students who had studied redox and electrochemistry.

In the practicality test, an instrument in the form of a practicality questionnaire was used with two chemistry teachers and nine phase F students at SMAN 8 Padang. The average result of the small group test with teachers is 97% with a category of Very Practical. The average result of the small group test with students is 92% with a category of Very Practical. The practicality

of the developed teaching materials is assessed based on ease of use, appearance, learning efficiency, and benefits.

During the student practicality stage, students were also asked to solve a problem presented using multiple chemical representations. This aimed to demonstrate that the multiple chemical representations provided in the developed teaching materials can assist students in discovering and understanding the concepts of redox and electrochemistry. The following is an image of the multiple chemical representations presented in the question given to the students.

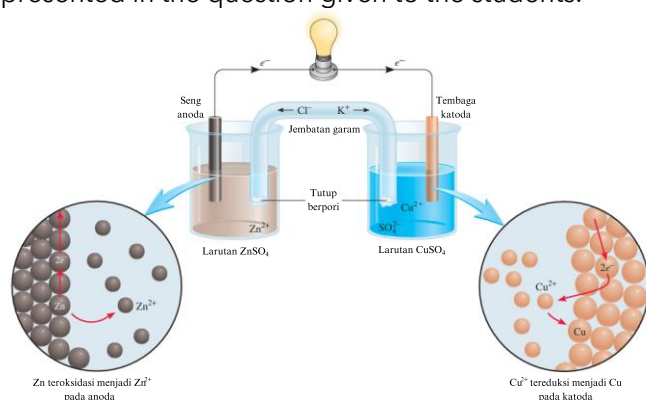


Figure 9. The Multiple Representations in the Question Given to the Students.

Based on the results from the practicality stage, it can be concluded that the clear instructions and questions significantly aided students in understanding the concepts and responding effectively. The content and representations in the developed teaching materials also helped students build and refine their mental models of redox and electrochemistry concepts. Furthermore, the teaching materials were user-friendly and did not impede the learning process. Therefore, the materials are deemed practical. The results from this stage are illustrated in the following diagram.

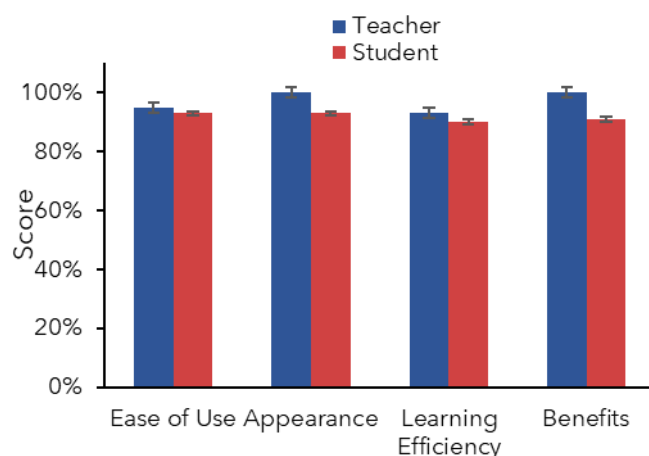


Figure 10. The practicality of the module evaluated by teachers and students

The graph depicts the practicality test results of a module as evaluated by both students and teachers, highlighting four key criteria: ease of use, appearance, learning efficiency, and benefits. Overall, both groups rated the module highly across all categories, indicating its effectiveness and practicality in the educational setting. Teachers consistently rated the module slightly higher than students, suggesting their confidence in its usability and potential to facilitate learning. In terms of ease of use, both groups found the module user-friendly, indicating that the interface and content structure were accessible and straightforward. For appearance, the scores reflect that the module's design and visual appeal effectively engaged both students and teachers, which is crucial for maintaining attention and interest during learning. Regarding learning efficiency, the module demonstrated strong results, showcasing its ability to enhance understanding and retention of material. Teachers likely appreciated the alignment of the module with curricular goals, while students benefited from the clear and structured presentation of information. Finally, in the category of benefits, both groups acknowledged the module's value in improving the learning experience and achieving educational outcomes. Teachers' higher scores in this area suggest their perspective on the module's long-term impact and versatility in various educational contexts. The relatively small gap between teacher and student scores across all criteria reflects a shared positive perception of the module, affirming its practicality and relevance. These results indicate that the module has been well-designed and successfully bridges the gap between teacher facilitation and student engagement, but minor refinements based on user feedback could further enhance its overall effectiveness.

CONCLUSION

This study successfully developed teaching materials for the Merdeka Curriculum in redox and electrochemistry using the Plomp model. The materials' high validity and practicality scores indicate they are well-suited to improve students' conceptual understanding and mental modeling of these complex topics. The developed materials have been validated with a construct validity score of 0.87, which is considered valid. Additionally, these materials received a high practicality rating, with 97% from teachers and 92% from students, demonstrating that they are both well-developed and suitable for supporting the Merdeka Curriculum, particularly in redox and electrochemistry. Furthermore, the materials feature comprehensive chemical representations that help students build mental models and enhance their understanding of concepts. The practical implications of this study show that these materials can improve student engagement and experience in challenging scientific areas. Future research could focus on evaluating the effectiveness of these materials in

enhancing student learning outcomes and exploring their impact in various educational contexts.

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