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Research Artikel

DEVELOPMENT OF REDOX REACTION LEARNING MEDIA BASED ON MULTIPLE REPRESENTATIONS

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Abstract

The use of Information & Communication Technology (ICT) media is widespread in education, thus necessitating the facilitation of chemistry learning activities that guide students to study redox materials. This research aims to design a learning media product—an android application—on redox reaction materials based on MLR and to determine the feasibility level of this learning media product. The research method employed is a modified 4-D model reduced to 3-D, which includes the stages of define, design, and develop. The research instruments include interview sheets, student needs questionnaires, student learning styles, validation by subject matter and media experts, as well as student responses. The final results of this research reveal that the Android application learning media product on redox materials based on MLR is deemed feasible. This is supported by the Aiken's V coefficient value of 0.86 which is in the very feasible category, and limited development trials achieving an ideal percentage of 80.65%, falling into the feasible category.

Keywords*: Android application; learning media; multiple level representation; redoxs material.*

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INTRODUCTION

In the 21st century, the use of information and communication technology (ICT) media has rapidly and extensively developed in Indonesia's education sector. One significant innovation is the integration of smartphones into every subject, including chemistry. The benefits of Android smartphones have been developed as a media for chemistry learning in the form of applications, making the learning process more engaging and interactive, and helping to visualize abstract chemistry concepts (Cahyana, Fitriani, & Utari, 2021; Cahyana, Paristiowati, & Fauziyah, 2018; Fibonacci, Azizati, & Wahyudi, 2020). These ICT media can serve as alternative sources and media for chemistry learning that are easily accessible independently and flexibly by students. Furthermore, the use of technology can maximize students' learning activities by providing opportunities to study chemistry materials that are not yet understood and to review lessons outside school hours without being constrained by time or place (Astiningsih & Partana, 2020; Cahyana Paristiowati, & Fauziyah, 2018; Fibonacci, Azizati, & Wahyudi, 2020; Cahyana, Fitriani, & & Utari, 2021; Milama, Adiliyah, & Fairusi, 2023). Therefore, the use of ICT in chemistry learning media is very important and needed in the current era to improve the quality of chemistry learning for students.

Based on the results of a student analysis survey conducted at Vocational High School 3 Pekalongan, chemistry material, particularly on redox reactions, is still considered by students as a difficult and abstract concept to learn. The numerous rules in determining the oxidation state of substances in a molecule pose their own challenges (Nazar et al., 2022). Moreover, redox material involves studying the occurrence of reduction and oxidation reactions, where the release and capture of electrons in redox reactions are abstract or invisible events (submicroscopic) (Harianto, Suryati, & Khery, 2017). The abstract and submicroscopic nature of chemistry material can make it difficult for students to interpret according to the concepts being studied (Şendur, Toprak, & Pekmez, 2010). Therefore, students need a multiple-level representation (MLR) learning basis to help them understand and visualize these abstract chemistry concepts. MLR in chemistry learning consists of macroscopic, submicroscopic, and symbolic levels (Johnstone, 2006; Kozma, 2003; Treagust, Chittleborough, & Mamiala, 2003). Students can achieve conceptual understanding and meaningful learning by linking visible changes (macroscopic) with processes at the particle or molecular level (submicroscopic), and writing them in correct chemistry notation (symbolic) (Gilbert & Treagust, 2009; Hatimah & Khery, 2021; Wahdatillah, Noer, & Anwar, 2022).

Based on the results of interviews with chemistry teachers at Vocational High School 3 Pekalongan, the chemistry learning process has not yet fully integrated the MLR approach effectively. The teaching of redox material is still limited to the symbolic and macroscopic levels, with the main focus on the symbols of reaction equations. The interconnection between the three levels of representation (macroscopic, submicroscopic, and symbolic) has not been fully realized. However, the importance of linking these three levels of representation is recognized as key to students' success in deeply understanding chemistry (Farida et al., 2017; Gilbert & Treagust, 2009; Helsy et al., 2017; Mashami & Gunawan, 2018). Furthermore, according to the interviews with chemistry teachers at Vocational High School 3 Pekalongan, the learning media used to demonstrate MLR have not been varied, and there is a lack of media in the form of Android applications to support chemistry learning, particularly in redox material. This is due to the use of conventional teaching materials such as text and electronic books, student worksheets, learning videos, and PowerPoint presentations. Therefore, innovative learning media are needed to visualize chemistry study objects more concretely, making it easier for students to understand redox material better.

Redox reactions taught using textbooks are usually limited to the macroscopic and symbolic levels in the form of chemistry reactions written in chemistry notation, making it difficult to illustrate redox reactions with all three levels of chemistry representation. This requires students to understand more concepts and memorize to solve problems in the material (Cahyana Fitriyani, & Utari, 2021; Fitriyah, Marsuki, & Affriyenni, 2022). Therefore, the role of Android application-based learning media is appropriately integrated with the MLR basis in redox reaction learning. This is because the advantages of these media can visualize MLR comprehensively in one application using features such as moving animations, videos, and 3D images.

Many previous studies on the development of chemistry learning media products in the form of Android applications have shown positive results on students' academic performance and chemistry learning outcomes. However, it is difficult to find specific research themes related to Android application learning media on redox material based on MLR. Similar research on the development of Android application products on redox material by Jatmiko, Sugiyarto, & Ikhsan (2018), showed that the use of Android applications can support students' independent learning on redox material, but it is not yet equipped with guidelines for independent practicum activities. In addition, the development of these Android applications is still very limited or does not fully relate the content with the three levels of chemistry representation. Research by Nazar et al., (2022), stated that the development of Android applications on redox material mostly presents content in text form without multimedia features such as images, videos, or animations. Research by Khoironi, Purwanto, & Priyasmika (2022), stated that the weakness of the developed Android application products is the need to design more interactive exercise questions and add animation features that connect the MLR aspects with redox material. Based on the weaknesses of previous research, the novelty of this study is to develop a learning media product in the form of an Android application that links redox material content with the three levels of chemistry representation. In addition, this Android application includes several multimedia features (3D images, moving animations, and videos) that can help students visualize chemistry material and is equipped with guidelines for independent practicum activities and interesting exercise questions. This Android application can also be accessed with or without an internet connection, making it easier to use. Therefore, it is important to conduct specific research on the development of learning media in the form of an Android application for redox material based on MLR that can be used as an effective learning media.

METHOD

The research method used in this study is Research and Development (R&D) with the 4-D development model (Thiagarajan, Sammel, & Sammel, 1974). The 4-D model consists of four main stages: define, design, develop, and disseminate. This study is limited to the develop stage, not including the disseminate stage. The research procedure flow is shown in Figure 1.

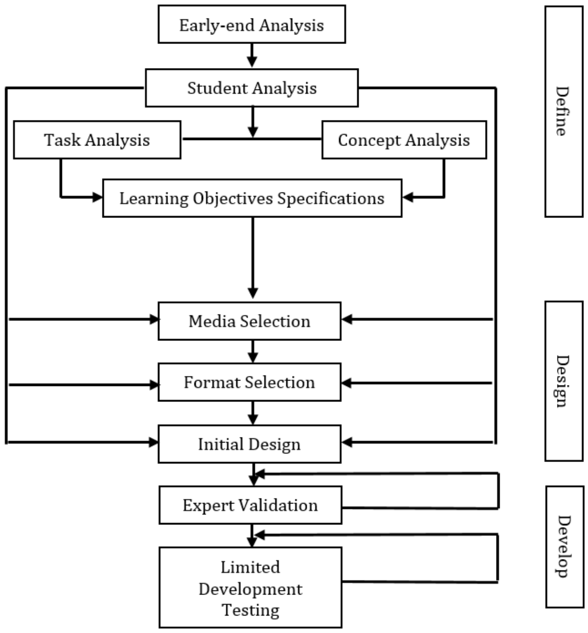

Figure 1. Research Procedure Flow

Stage I : Define

The define stage is the initial observation stage at Vocational High School 3 Pekalongan, aimed at determining and explaining the requirements needed to design the learning media product. This stage consists of five steps: early-end analysis, student analysis, task analysis, concept analysis, and analysis of learning objectives specifications. First, the early-end analysis aims to map out the basic problems faced by teachers and students in chemistry learning and then find solutions. This step is conducted through interviews and questionnaires to identify materials, learning resources, methods, gadget usage, and other aspects in chemistry learning activities. Second, the student analysis aims to understand the needs and learning styles of students in chemistry learning so that the learning media product matches the characteristics of the students. Third, the task analysis aims to identify the distinctive features of the tasks given by the teacher to the students. Fourth, the concept analysis aims to recognize redox material based on the core and basic competencies that align with the 2013 Curriculum syllabus. Fifth, the analysis of learning objectives specifications aims to break down the content of the basic competencies into more detailed competency achievement indicators, which are then formulated as learning objectives that students can achieve through the Android application learning media for redox material based on MLR.

Stage II : Design

The design stage involves the initial design of the learning media product. This stage includes three steps: media selection, format selection, and initial design. First, media selection aims to identify the type of learning media product that matches the characteristics of the students and the results from the define stage analysis. Second, format selection aims to design the learning tool in a way that ensures the developed media can accommodate students' needs. This step is crucial so that the learning media product is not only engaging and easy to understand but also supports the students' learning process. Third, the initial design aims to produce the overall design of the learning media product based on the results of the previous analyses.

Stage III : Develop

The develop stage involves creating a valid or high-quality learning media product. This stage includes two steps: expert validation and limited development testing. Expert validation aims to evaluate the feasibility of the learning media product by seeking input from experts in the fields of content and media. Meanwhile, limited development testing is conducted to gather feedback from students regarding the feasibility of the developed learning media product.

This research was conducted at Vocational High School 3 Pekalongan with a population of tenth-grade students and a limited development testing sample of nine students, representing those with the highest, average, and lowest abilities, with three students in each category.

Data collection techniques included interviews and questionnaires. Structured interviews were conducted with chemistry teachers to obtain detailed information regarding student characteristics and chemistry learning activities. Questionnaires used included various types, such as needs analysis questionnaires for students, student learning style, chemistry material validation, learning media validation, and student feedback questionnaires. Expert validation and student feedback questionnaires used a Likert scale for measuring responses and validity (Widoyoko, 2009).

Data obtained from expert validation assessments and student feedback were analyzed using Aiken’s V validity method (Azwar, 2012).

$$V = \frac{\sum s}{[n(C-1)]}$$

Keterangan:
s : r – lo
r : score from the validator
lo : lowest value score (1)
C : highest value score (5)
n : number of validators

The Aiken's V coefficient values obtained are interpreted based on the criteria listed in Table 1 (Retnawati, 2016).

Table 1. Aiken’s V Valid Criteria

Index	Feasibility Categories
0.81 – 1.0	Very Feasible
0.41 – 0.8	Moderately Feasible
< 0.4	Less Feasible

Subsequently, the data obtained from the limited development testing were calculated using the formula and criteria outlined in Table 2 (Widoyoko, 2009).

Table 2. Criteria for Limited Development Testing

Score Range (i)	Feasibility Categories
$X > \bar{X}_i + 1.8\ sb_i$	Very Good
$\bar{X}_i + 0.6\ sb_i < X \leq \bar{X}_i + 1.8\ sb_i$	Good
$\bar{X}_i - 0.6\ sb_i < X \leq \bar{X}_i + 0.6\ sb_i$	Sufficient
$\bar{X}_i - 1.8\ sb_i < X \leq \bar{X}_i - 0.6\ sb_i$	Poor
$X \leq \bar{X}_i - 1.8\ sb_i$	Very Poor

First calculate the average score for each assessment component:

$$X = \frac{\sum X}{n}$$

Next, calculate the ideal average score and ideal standard deviation:

$$\bar{X}_i = \frac{1}{2}\,(\text{score max + min})$$

$$sb_i = \frac{1}{6}\,(\text{score max - min})$$

Keterangan:

X : average component scores

$\sum X$: sum of average component scores

n : number of validators

$\bar{X}_i$: average ideal score

sb_i : ideal standard deviation

RESULTS AND DISCUSSIONS

The result of this research is the development of a learning media product in the form of an Android application for redox reactions based on MLR. The development process of this product followed the 4-D model but was limited to the develop stage without including the disseminate stage.

Stage I : Define

a. Early-end Analysis

The results of the preliminary analysis revealed fundamental needs and problems identified at the school, leading to the development of a learning media product in the form of an Android application for redox reactions based on MLR. According to the initial needs analysis questionnaire, 71% of students still find chemistry material, including redox reactions, difficult to learn. Additionally, the chemistry learning process is perceived as less engaging by some students, resulting in a lower understanding of the material. This issue is attributed to a lack of engaging and innovative learning resources and media. Interviews with teachers indicated that the MLR-based chemistry learning process has not fully integrated the chemistry material comprehensively, especially as redox reactions are only covered at the macroscopic and symbolic levels. Currently used teaching materials include textbooks and electronic resources in PDF format, PowerPoint presentations, and others, but there is a lack of chemistry learning media in the form of an Android application.

b. Student Analysis

The development of this learning media product is tailored to the characteristics and learning styles of students to enhance its effectiveness and meet their needs. Currently, 90.3% of students use Android smartphones both at school for learning purposes and outside of school, and have access to the internet. Additionally, 74.2% of students use their gadgets for more than 6 hours a day. Furthermore, 54.84% of students have a kinesthetic learning style. Kinesthetic learners tend to engage in learning through movement, actions, and physical interaction, which involves the use of touch and motor activities (Papilaya & Huliselan, 2016).

c. Task Analysis

The task analysis aims to design practice exercises that align with the competencies of redox material from the syllabus, which will be incorporated into the learning media product. The analysis results indicate that the tasks assigned by teachers include practice exercises that connect redox material with environmental phenomena relevant to students. However, these exercises have not yet been linked with MLR.

d. Concept Analysis and Learning Objectives Specification

In general, the concepts of redox reactions presented in the learning media product include the concepts of redox reactions, determining oxidation numbers, reductants and oxidants, and the nomenclature of compounds. The specification of learning objectives involves detailing the results of the concept analysis into specific learning goals that the media aims to achieve.

Based on the description from the define stage, an appropriate chemistry learning media is required to enhance students' understanding of chemistry concepts and motivation to learn, while ensuring ease of use and the media's ability to visualize abstract chemistry concepts effectively.

Stage II : Design

a. Media Selection

The ICT media used is Android smartphones, as nearly all students own one, which allows them to download and access the application via the Google Play Store. This provides added value to the chemistry learning application. The Android application is designed using Smart Apps Creator (SAC) 3 software, which is operated through a laptop. The content presented in the learning media product is focused on redox reactions.

b. Format Selection

The chosen format for the learning media product is .apk (Android Package Kit), with a file size of 79.8 Megabytes (MB). This learning media product is designed to be mostly accessible offline, except for one video from YouTube that requires online access. This decision is based on the questionnaire results, where 48.4% of students indicated they do not mind downloading an application of up to 100 MB, and 80.6% of students are able to access YouTube videos online. The chemistry learning basis applied in this product is MLR, which includes macroscopic, submicroscopic, and symbolic levels in each discussion of redox reactions. The multimedia content desired by students includes moving animations, videos, and 3D images. These multimedia elements are provided to visualize abstract chemistry concepts (Wahdatillah, Noer, & Anwar, 2022).

c. Initial Design

The initial design of the learning media product includes several features as follows: (1) Cover page; (2) Main menu; (3) Redox reaction materials menu; (4) Practice exercises; (5) Competencies; (6) Concept map; (7) Media usage instructions; (8) Media information; (9) Developer information; and (10) Summary and reference. Examples of the initial design for the screen layouts of the learning media product, before being validated by experts, including the screen layout of the apperception menu, are presented in Figure 2.

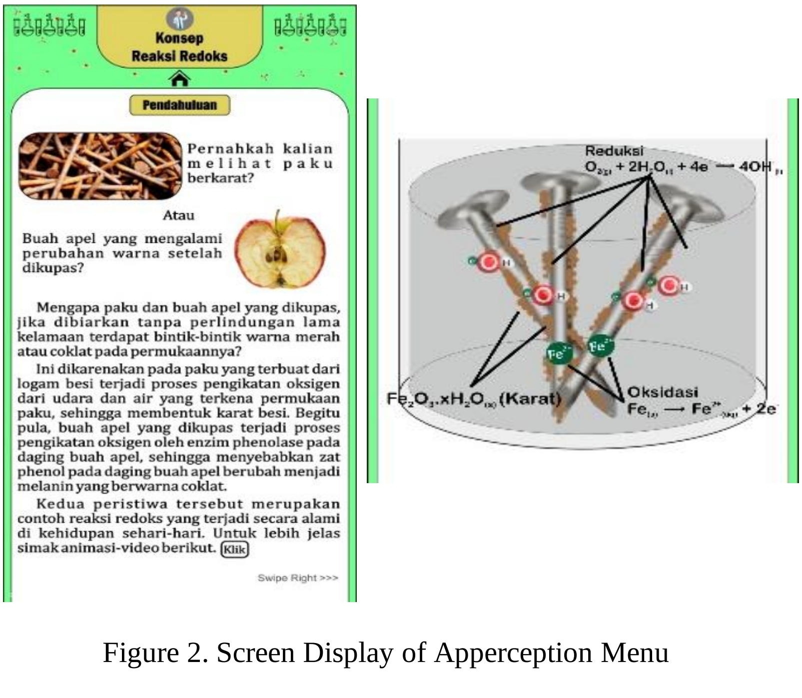

Figure 2. Screen Display of Apperception Menu

The introduction section includes a apperception menu designed to introduce the basic concepts of redox reactions to students. This menu provides examples of environmental phenomena linked with the MLR approach. The macroscopic level, the first tier, illustrates chemistry concepts based on experience or experimental results (Li & Arshad, 2014). The submicroscopic level provides a detailed view of the chemistry reactions occurring (Davidowitz, Chittleborough, & Murray, 2010). The symbolic level represents chemistry concepts through chemistry notation or reaction equations (Talanquer, 2011). The goal of this apperception menu is to stimulate students' curiosity and motivation to learn, as well as to facilitate a more meaningful understanding of chemistry by comprehensively understanding a chemistry phenomeno (Hatimah & Khery, 2021; Helsy et al., 2017; Mashami & Gunawan, 2018; Wahdatillah, Noer, & Anwar, 2022). The appperception is presented in the form of an animated video that includes explanations related to the rusting of iron nails and the color change in apple flesh exposed to open air.

Figure 3 displays the "Self-Practice Menu," which contains instructions for experiments that students can conduct at home. This guide uses tools and materials that are easily obtainable. This menu is designed as a solution for students with a kinesthetic learning style. Kinesthetic learning occurs when students use physical activities to connect concepts with real-world applications, such as through practical experiments (Scanlan, Kennedy, & McCarthy, 2021). Kinesthetic learners tend to find it challenging to remain still for long periods in front of a smartphone screen. They are more effective in receiving instructional material while engaging in physical or interactive activities related to the information they are learning (DePorter & Hernacki, 1992).

Figure 3. Screen Display of Self-Practice Menu

Figure 4 shows the "Practice Exercises Menu" included in the learning media product. This menu offers a variety of questions based on the MLR approach. The practice exercises include 10 multiple-choice questions with explanations for the correct answers, allowing students to correct their understanding if they make mistakes. Additionally, there are 10 matching questions where students are required to drag the correct answers into the provided columns. These exercises aim to prevent student boredom. After completing all the available practice exercises, students will see a screen displaying the score they achieved.

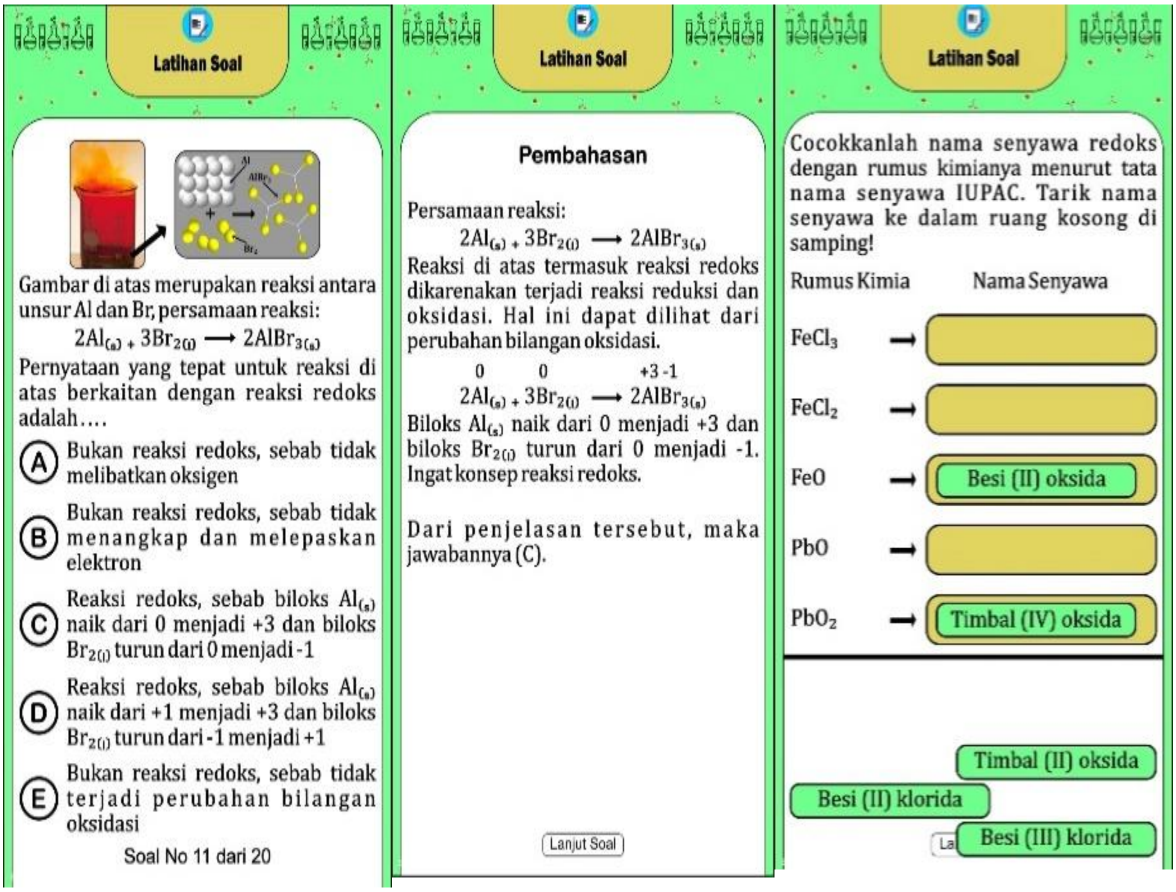

Figure 4. Screen Display of Practice Exercises

Stage III : Develop

a. Expert Validation

Validation by experts was conducted in two stages: validation of the chemistry content and the learning media. This validation process involved two chemistry lecturers and one chemistry teacher who provided their assessments and evaluations of the learning media product. The validation assessment was based on various pre-established aspects and indicators. The results of the expert validation of the learning media product are presented in Table 3.

Table 3. Expert Validation Assessment Results

Validator	Average Number of Validator Scores (r)	s
Validator I	4.36	3.36
Validator II	4.73	3.73
Validator III	4.2	3.2
	$\sum$s	10.29
	V	0.86
Feasibility Categories		Very Feasible

The Aiken's V coefficient obtained is 0.86, which falls into the "very feasible" category according to the validation criteria in Table 1. The MLR-based Android application learning media product is thus considered very feasible and ready for limited development testing.

b. Limited Development Testing

Limited development testing, or small-scale trials, was conducted with nine students selected based on predefined criteria. The testing was carried out in a single session via WhatsApp and Google Meet. Students were asked to install and familiarize themselves with the MLR-based Android application learning media to facilitate the learning process. The learning media was used throughout the session, during which students studied redox reactions. After the learning activity, students were given a questionnaire to provide feedback on the MLR-based Android application learning media for redox reactions via Google

Forms. The results of the students' feedback on the feasibility of the learning media product are presented in Table 4.

Based on Table 4, students' feedback on the aspects of content quality and appearance each received an ideal percentage of 82.20% and 82.50%, respectively, placing them in the "good" category. Students found the material presentation in the learning media to be easy to understand and beneficial. Each section on redox reactions was visualized through moving animations, reaction videos, and 3D images, which facilitated students' understanding of the material. This finding aligns with the research of Harianto Suryati, & Khery (2019); Helsy et al., (2017); Jatmiko Sugiyarto, & Ikhsan (2018); Mashami & Gunawan, (2018), which suggests that moving animations, videos, and 3D images can help and ease students' understanding and visualization of abstract chemistry concepts. However, there were suggestions for future improvements regarding the animation display to make it more engaging. An example of the screen display is shown in Figure 5.

Table 4. Results of Student Response Questionnaire

Assessment Aspects	%	Category
Content Quality	82.20	Good
Appearance	82.50	Good
Enjoyment	78.90	Good
Motivation	83.30	Good
Language	82.20	Good
Usability	78.90	Good
Independence	71.10	Good
Multiple Level Representation	77.80	Good

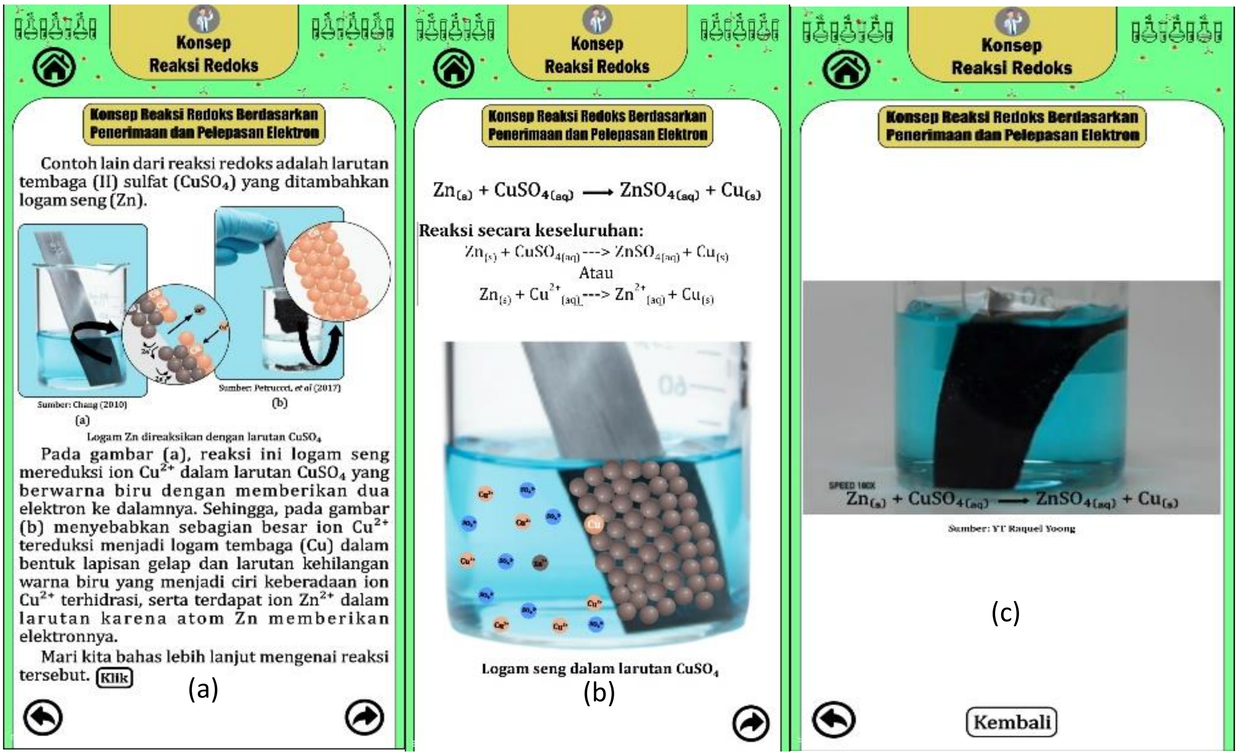

Figure 5. Screen Display of MLR-Based Redox Material

Figure 5 also illustrates the application of the three levels of chemistry representation in the redox material within this Android application. For example, the reaction between a zinc metal plate and copper (II) sulfate solution in a beaker is shown. At the macroscopic level, students can observe the visible chemistry reaction through images and videos, as depicted in Figures 5a and 5c, where the reaction forms a brown solid precipitate on the surface of the zinc metal plate. After observing this chemistry reaction, to understand what happens at the submicroscopic level, students can view the movement or transfer of electrons through an animated video, shown in Figure 5b. This animation demonstrates that zinc metal atoms replace the copper (II) ions from the salt solution, and the blue color of the solution, indicating hydrated copper (II) ions, will fade.

Finally, at the symbolic level, the chemistry reaction is represented by a chemistry equation or notation, as shown in Figure 5b (Li & Arshad, 2014).

The aspects of enjoyment and motivation received ideal percentages of 78.90% and 83.30%, respectively. This is because students enjoy learning easily with gadgets, as they currently find learning with gadgets more comfortable than using textbooks (Khoiorni, Priatmoko, & Prasetya, 2023). Additionally, the use of gadgets can stimulate the motivation to conduct independent practical experiments, as shown in Figure 3. Chemistry learning media can enhance student motivation if it includes clear and engaging visualizations, flexibility, and varied practice questions (Prasetyo et al., 2015).

The aspect of language use received an ideal percentage of 82.20%. This is because students found that the delivery of content in the learning media was easy to understand and fairly clear. The aspects of usability and independence received ideal percentages of 78.90% and 71.10%, respectively. Some students appreciated using this learning media because it can be accessed anytime and anywhere without needing an internet connection, and it supports independent learning. This is in line with findings by Astiningsih & Partana (2020); Cahyana Paristiowati, & Fauziyah (2018); Cahyana, Fitriani, & Utari (2021); Ewais et al., (2021); Nazar et al., (2022); Syarifuddin et al., (2023), which indicate that Android applications are very helpful for students, particularly due to their practical usability, enabling flexible and independent access. Students can more easily find information, facts, and content (Machmud, 2018). However, some students still felt confused using this media due to unfamiliarity with Android application learning tools. Therefore, there are suggestions for improvement to make the application easier to operate. An example is the difference in the layout of the left and right buttons and the home button before and after revisions, as shown in Figure 3 and Figure 5, respectively.

The aspect of MLR received an ideal percentage of 77.80%. This is because some students felt they could understand redox material more deeply as the content was presented through everyday phenomena linked with the three levels of chemistry representation, as shown in Figure 2. The MLR basis in the learning media displays redox reaction concepts at the macroscopic level through images or videos that show chemistry reactions, allowing students to observe reactions directly. At the submicroscopic level, the concepts are visualized using 3D images, animated videos, or videos showing electron or molecular movement in chemistry reactions. At the symbolic level, these concepts are represented through reaction equations or chemistry notation. However, some students still felt unfamiliar or unaccustomed to connecting these three levels of representation with redox material.

In general, it can be concluded that based on the student response questionnaire, the redox reaction learning media application based on MLR received an ideal percentage of 80.65%. This indicates that the product received positive feedback from students and falls within the "good" feasibility category for use as a chemistry learning media.

The learning media product developed in this study possesses several important characteristics. Firstly, the product is capable of visualizing the abstract concept of redox reactions in a more tangible and engaging manner using the MLR approach. Secondly, the product has good accessibility as it can be used offline and downloaded via the Google Play Store. Thirdly, it offers flexibility. Fourthly, it includes a variety of exercises to enhance student understanding. Fifthly, the product provides a self-guided practical experiment guide for students to learn from home. Research by Husna & Zainul (2019); Lubis & Ikhsan (2015) indicates that chemistry learning media in the form of Android applications yields positive results in improving students' learning outcomes and academic performance. This finding is consistent with the research conducted by Cahyana, Fitriani, & Utari (2021); Cahyana, Paristiowati, & Fauziyah (2018); Jatmiko, Sugiyarto, & Ikhsan (2018); Putra et al., (2020), which suggests that Android applications can enhance chemistry concept comprehension and facilitate independent learning for students.

Based on the evaluations from expert validation and limited development testing, the learning media product developed is deemed highly suitable and effective for use in chemistry instruction. Expert validation yielded an Aiken's V coefficient of 0.86, classified as "very feasible." Meanwhile, the testing results showed an ideal percentage of 80.65%, categorized as "good." These findings are consistent with research by Lubis et al., (2015); Ramdani, Jufri, & Jamaluddin (2020); Solihah et al., (2015), which indicates that when an Android-based chemistry learning media has been deemed feasible, it can effectively serve as a supporting tool in the learning process.

CONCLUSION

The results of this study produced a learning media product in the form of an Android application for redox reactions based on MLR. This learning media product has undergone expert validation with a "very feasible" rating and limited development testing with positive feedback. Therefore, the Android application for redox reactions based on MLR can be utilized as a chemistry learning tool for students. Future research should include testing up to the dissemination stage to measure the product's effectiveness on a broader scale. Additionally, there is a need to develop Android applications based on other chemistry approaches and materials.

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