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Development of Interactive E-Book Based on Chemical Representation on Voltaic Cell Topic

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Abstract: Development of Interactive E-Book Based on Chemical Representation on Voltaic Cell Topic. This research was aimed to develop interactive e-book based on chemical representation on voltaic cell topic, describe the validity and characteristics, describe the teachers' and students responses on interactive e-book based on chemical representation on voltaic cell topic. The research design used R&D method by Borg&Gall which consists of ten stages, but in this research it was only carried out until the fifth stage, is the revision of the field trial result. The instrument used in this research is questionnaires. The data obtained were analyzed using descriptive statistical analysis. Interactive e-book based on chemical representation on voltaic cell topic was validated by expert, covering aspects of content suitability, construction, and readability. Based on the validation results, this e-book categorized in very high criteria and is declared valid. The teachers responses to this e-book on the aspects of content suitability, construction, and readability is categorized in very high criteria. The students responses to this e-book on the aspects of attractiveness and readability is categorized in very high criteria. Characteristics of this e-book is starting with discourses related in everyday life phenomenas accompanied by pictures and videos based on chemical representation, eqquiped with identification columns, explanation columns, and interactive evaluations.

Keywords: *Interactive E-book, Chemical Representation, Voltaic Cell*

Abstrak: Pengembangan *E-Book* Interaktif Berbasis Representasi Kimia Pada Materi Sel Volta Penelitian ini bertujuan untuk mengembangkan *e-book* interaktif berbasis representasi kimia pada materi sel volta, mendeskripsikan karakteristik, dan validitas *e-book*, serta mendeskripsikan tanggapan guru dan tanggapan peserta didik terhadap *e-book* interaktif berbasis representasi kimia pada materi sel volta. Desain penelitian yang digunakan adalah penelitian dan pengembangan menurut Borg & Gall yang terdiri dari sepuluh tahap, namun pada penelitian ini telah dilakukan sampai tahap kelima yaitu revisi hasil uji coba. Instrumen yang digunakan pada penelitian ini adalah angket. Data yang diperoleh dianalisis menggunakan analisis statistik deskriptif. *E-book* interaktif berbasis representasi kimia pada materi sel volta ini dilakukan validasi ahli yang

meliputi aspek kesesuaian isi, konstruksi, dan keterbacaan. Berdasarkan hasil validasi, *e-book* yang dikembangkan memiliki kriteria sangat tinggi, sehingga dikatakan valid. Tanggapan guru terhadap *e-book* yang dikembangkan pada aspek kesesuaian isi, konstruksi, dan keterbacaan semuanya memiliki kriteria sangat tinggi. Tanggapan peserta didik terhadap *e-book* interaktif yang dikembangkan pada aspek kemenarikan dan keterbacaan semuanya memiliki kriteria sangat tinggi. Karakteristik *e-book* interaktif berbasis representasi kimia pada materi sel volta, diawali dengan wacana terkait fenomena dalam kehidupan sehari-hari yang disertai gambar dan video berbasis representasi kimia, dilengkapi dengan kolom identifikasi, kolom penjelasan dan soal evaluasi yang interaktif.

Kata kunci: *E-book interaktif, Sel volta, Representasi kimia*

▪ INTRODUCTION

A quality learning process is determined not only by the strategies implemented by teachers, but also by the use of varied and appropriate learning resources. In the 21st-century education era, learning resources play a crucial role in helping students understand concepts, improve thinking skills, and solve problems (Mulyono & Ampo, 2021). Selecting the right learning resources can make learning more active and connect material to real-world contexts, thus providing students with a more meaningful learning experience (Padang & Sitepu, 2022). Therefore, optimal utilization of learning resources is a crucial step in improving the quality of the learning process and student outcomes (Ikawati, 2024).Menurut Association for Educational Communication and Technology (AECT), Learning resources are all forms of resources, whether data, people, or specific objects, that students can utilize in the learning process. These resources can be used separately or in an integrated manner to help students achieve their desired goals or competencies (Cahyadi, 2019).

With the development of information and communication technology (ICT), learning resources are no longer limited to printed materials or physical environments, but have also expanded to various digital media such as videos, electronic modules, simulations, and LMS platforms. One form of digital learning resource that is increasingly used is the e-book, which offers easy access, interactive features, and a more dynamic presentation of material compared to printed books. Therefore, optimizing ICT-based learning resources, including e-books, is an important strategy for improving the quality of learning in the digital era (Wibawa & Mahendra, 2023). Several studies on the effectiveness of using e-books as independent learning resources show that they can encourage students to be more active in the learning process without relying too much on teacher explanations. The use of e-books has also been shown to have a positive effect on learning motivation and significantly improve students' thinking skills (Almaida, N. et al., 2023; Danardono, A. et al., 2019; Rosmawati, W., 2023).

E- Interactive books contain a network of digital information units consisting of text, graphics, video, animation, sound, and questions, all packaged in the form of flash animation visualizations combined in a single program equipped with color, sound, and music. Interactive e-books can be created by including multimedia content and their interactive nature allows students to interact with what they read. Interactive e-books can

also include learning evaluations that can directly provide responses in the form of grades to students (Ashshidiqqi, 2017).

Chemistry is a field of study that contains many abstract concepts. Some concepts cannot be explained without the help of analogies or models, so strong reasoning skills are required to understand them (Abduhan, Mulyani, & Utami, 2015). According to Johnstone in Sunyono (2015), chemistry learning should present three types of representations: macroscopic, submicroscopic, and symbolic. Macroscopic representations relate to chemical phenomena that can be directly observed by the five senses, such as through sight, smell, and touch. Meanwhile, submicroscopic representations describe chemical phenomena at the particulate level that cannot be directly observed, such as atoms, molecules, and ions. The term submicroscopic is used to indicate a level smaller than nanoscopic and is the basis for explaining macroscopic phenomena through the movement of particles such as electrons, molecules, and atoms. Symbolic representations present chemical phenomena using symbols, numbers, letters, or certain signs. In other words, the symbolic level describes chemical phenomena qualitatively and quantitatively through chemical formulas, reaction equations, diagrams, pictures, stoichiometry, and mathematical calculations (Widarti, 2022)

Students' chemical representation skills are strongly influenced by the classroom learning process, laboratory practical activities, and the learning resources used. However, the reality in the field shows that chemistry learning has not yet developed all three levels of chemical representation. Current chemistry learning generally still focuses on two levels of representation: macroscopic and symbolic. This condition hinders students in solving problems that require understanding at the submicroscopic level. As a result, students experience difficulties when asked to provide explanations for submicroscopic representations based on macroscopic or symbolic phenomena they observe or study (Widarti, 2022).

Several previous studies have developed interactive e-books based on chemical representations on various topics. Nur'aini et al. (2015) developed an interactive e-book on acids and bases; Arrasyid et al. (2017) applied it to electrolyte and non-electrolyte solutions; and Hidayanti et al. (2018) developed a similar e-book on buffer solutions. In general, the results of these studies indicate that the interactive e-books developed have a high level of feasibility in terms of construction, material suitability, readability, and attractiveness, making them acceptable and usable by teachers and students as learning resources. However, no research has been found specifically developing an interactive e-book based on chemical representations for voltaic cells. Therefore, the development of an "Interactive E-Book Based on Chemical Representations for Voltaic Cells" is deemed necessary.

This article aims to describe the level of validity, as well as the responses of teachers and students regarding the suitability of the content and readability of the interactive e-book based on chemical representation on the voltaic cell material that was developed, as well as to describe the characteristics of the interactive e-book.

▪ METHOD

The research design used in this study is the Research and Development (R&D) method according to Borg & Gall (1989), which consists of ten steps. However, the researcher limited the research and development stages to five steps because this study only focuses on the process of developing and testing the feasibility of e-books. These

research stages include: 1) Research and information collection, 2) planning, 3) developing a preliminary form of product, 4) preliminary field testing, and 5) revising the results of the trial (main product revision).

This research was conducted in Bandar Lampung City. Field studies were conducted in three schools, namely SMA Negeri 12 Bandar Lampung, SMA Negeri 14 Bandar Lampung, and SMA Negeri 15 Bandar Lampung. Data sources for the research and information collection stage consisted of one teacher and ten students in each school. The developed e-book was validated by expert validators, namely two lecturers from the Chemistry Education Study Program, University of Lampung. The trial of the developed e-book was conducted on three teachers at SMAN 15 Bandar Lampung and 30 students of class XII IPA 2 at SMAN 15 Bandar Lampung.

The data collection instruments used in this study include: (1) Teacher and student needs analysis questionnaires used in the research and information gathering stage; (2) Expert validation instruments in the form of questionnaires aimed at assessing the suitability of material content, construction aspects, and readability at the initial product development stage; (3) Teacher response questionnaires that assess the suitability of material content, construction, and readability, as well as student response questionnaires that assess readability and attractiveness at the initial field trial stage. Expert validation instruments, teacher and student responses use a Likert scale ranging from 1 to 5, a score of 1 indicates the lowest value and a score of 5 is the highest value.

The data analysis technique for the questionnaire results during the research and information collection stage was conducted using descriptive narrative. The data analysis technique for the expert validation results, teacher and student responses was conducted by calculating the total score of respondents' answers and the average percentage of the expert validation questionnaire, teacher and student responses to the developed e-book. After that, the percentage of overall questionnaire responses was interpreted using the interpretation according to Arikunto (2013) as shown in Table 1.

Table 1. Percentage interpretation

Percentage	Criteria
80,1% - 100%	Very high
60,1% - 80%	Tall
40,1% - 60%	Currently
20,1% - 40%	Low
0,0% - 20%	Very low

The final step is to interpret the expert validation criteria for analyzing the percentage of products resulting from expert validation using the interpretation according to Arikunto (2013) based on Table 2.

Table 2. Validation criteria

Percentage (%)	Validity Level	Description
100 – 76	Valid	Appropriate/no revision required
75- 61	Quite Valid	Quite appropriate/partial revision
60 – 26	Less Valid	Less appropriate/partial revision
<26	Not Valid	Not appropriate/total revision

▪ RESULT AND DISCUSSION

Research Results and Information Collection

Based on the results of questionnaires and interviews in the field study, it was revealed that chemistry teachers still rely on textbooks and the internet as their primary learning resources. The textbooks used, particularly for voltaic cells, were deemed incapable of fostering motivation or increasing students' enthusiasm for learning. Furthermore, none of the teachers utilized interactive e-books, and voltaic cell learning did not incorporate a chemical representation approach, particularly at the submicroscopic level, which is crucial for visualizing electrochemical processes. From the student perspective, the learning resources used were also dominated by textbooks and the internet. However, the available textbooks were unable to effectively help students understand the concept of voltaic cells because the illustrations presented were less engaging and the language used was relatively difficult to understand, thus still presenting obstacles to comprehensive mastery of the material. Both teachers and students agreed that the development of interactive e-books based on chemical representations was needed as an alternative learning resource. This finding aligns with research by Fitria and Sebastian (2024) which showed that the use of multiple representations through digital media can improve understanding of chemical concepts, making the development of teaching materials that integrate various levels of representation increasingly important.

Product Planning Results

At this stage, the results of product planning to be developed are the purpose of using e-books, e-book users, and e-book components. The purpose of using this interactive e-book is to help students in learning voltaic cell material, and to help teachers to create interactions between students and learning resources, as well as a reference for teachers in compiling and developing interactive e-books based on better representations. The users of this product are chemistry teachers and grade XII students. The components of this e-book are divided into three parts, namely 1) the introduction consisting of the outer cover, inner cover, foreword, e-book introduction, and table of contents and list of figures 2) the content section consisting of concept maps, learning achievement indicators, titles, and material descriptions, and 3) the closing section consisting of evaluation questions, bibliography, appendices and back cover. This is in accordance with the opinion of Maula, M. et al. (2025) that e-books present text content that conveys learning instructions, material descriptions, learning objectives, learning outcomes, and explanations of concepts and evaluation questions.

Results of the Development of an Interactive E-Book Based on Chemical Representation

At this stage, the development results were an interactive e-book based on chemical representations of voltaic cells. The applications or programs used in this development were Flip PDF Professional and Adobe Flash Professional CS6.

The construction of the interactive e-book based on chemical representations of voltaic cells consists of three parts: the front cover, which consists of the outer cover, the inner cover, the foreword, the e-book introduction, and the table of contents and list of figures. The outer cover displays the e-book title, the author's name, and displays images related to the voltaic cell material. The inside cover displays the title of the interactive e-

book, along with the class and interest group. The inside cover is designed more simply than the outside cover. The foreword contains the author's gratitude for the product's completion and thanks to those who helped in the development of this interactive e-book. The e-book introduction contains a description of the e-book, instructions for using the e-book, and the benefits of using the e-book. The table of contents and list of figures aim to make it easier for readers to find the pages of the material they want to study and the pages of the images they want to view..

The content section consists of a concept map, competency achievement indicators, a title, and a material description. The concept map contains a schematic diagram representing meaningful relationships between one concept and another. The title is written in bold for each subtopic, aiming to clarify the material to be explained in this interactive e-book. The material description is organized into six main sections: first, redox reactions; second, circuits and reactions in voltaic cells; third, voltaic cell notation; fourth, standard hydrogen electrodes, standard electrode potentials, and cell potentials; fifth, the voltaic series; and sixth, dry cells, lithium batteries, silver oxide cells, and accumulator cells as practical applications of voltaic cells in everyday life.

The closing section consists of evaluation questions, a bibliography, appendices, and the back cover. The evaluation questions in the developed e-book are interactive so that students can immediately see their scores after completing the evaluation questions. The bibliography contains sources of material used in the interactive e-book on voltaic cells. The appendices contain tables of standard reduction potentials (SRPs) for each electrode. The back cover of this e-book contains a general description of the e-book and a profile of the interactive e-book author.

The next step, after drafting the e-book, was expert validation. This expert validation was conducted by two lecturers from the Chemistry Education Department of the University of Lampung. The expert validation included validation of content suitability, construction, and readability. The percentages of the two validators' assessments of the interactive e-book based on chemical representations of voltaic cells are shown in Table 3.

Table 3. Percentage of expert validation results

No	Rated aspect	Percentage	Criteria
1	Content suitability	98,46%	Very high
2	Construction	99,17%	Very high
3	Legibility	93,48%	Very high
	Average	**97,04%**	**Very high**

Based on the validator's assessment of the interactive e-book based on chemical representations of voltaic cells, it was found that the developed interactive e-book met the very high criteria with a score of 97.04%. Based on Arikunto's (2013) validation criteria, the interactive e-book based on chemical representations of voltaic cells was deemed valid and suitable for use in learning.

Regarding content suitability, the validator assessed the alignment of the interactive e-book with learning outcome indicators, the sequence of material presentation based on the indicators, and the suitability of the material to the level of chemical representation. The assessment results showed a very high score with a score of 98.46%, thus declaring the e-book suitable for use. This finding aligns with Biggs and Tang (2016), who

emphasized that learning materials must be structured in alignment with learning outcomes and indicators to support the achievement of learning objectives.

Regarding construction, the assessment assessed the completeness of the e-book components and the clarity of the material explanations in the developed interactive e-book. The validation results showed a very high score with a score of 99.17%, thus declaring the e-book suitable for use. These findings align with Prastowo's (2018) opinion, which states that good teaching materials must contain comprehensive learning components, with a mutually supportive integration of text, images, animations, and videos to facilitate student understanding.

In terms of readability validation, the assessment included variations in font size and shape, image quality, color combinations, clarity of captions for images and tables, and the use of language that conforms to the General Guidelines for Indonesian Spelling (PUEBI), is communicative, and easy to understand. The validation results showed a very high score of 93.48%, thus declaring the e-book suitable for use. This finding aligns with research by Barus, Utomo, and Darmawan (2025), which found that font type, size, and color contrast significantly influence text readability and reading comfort in digital media.

The e-book was further improved based on the validator's suggestions. These included improvements to the competency achievement indicators, including improvements to the order of indicators and the wording of these indicators. Furthermore, attention was paid to the color combination used in charts and text in the concept map section.

Initial Field Trial Results

The initial field trial phase was conducted by distributing questionnaires and administering validated and revised initial products. The teacher response questionnaire included assessments of content suitability, construction, and readability, while the student response questionnaire included assessments of interestingness and readability. The percentage of teacher responses to the initial field trial results can be seen in Table 4.

Table 4. Percentage of results of initial field trials on teachers

No	Rated aspect	Percentage	Criteria
1	Content suitability	87,69%	Very high
2	Construction	94,44%	Very high
3	Legibility	88,12%	Very high
	Average		**Very high**

Based on the results of the teacher response questionnaire, the interactive e-book based on chemical representations received a very good rating for content suitability, construction, and readability. Teachers assessed that the material presented was aligned with learning outcomes and systematically structured, the e-book components were complete and integrated, and the visual display and language were easy to understand. The high teacher response indicated that the interactive e-book based on chemical representations was deemed suitable for use in chemistry learning.

The percentage of initial field trial results with students can be seen in Table 5.

Table 5. Percentage of initial field trial results with students

No	Rated aspect	Percentage	Criteria
1	Attractiveness	97,17%	Very high
2	Readability	97,38%	Very high
	Average	**97,27%**	**Very high**

Based on the results of the student questionnaire, the interactive e-book's appeal and readability achieved an average rating of 97.27%, with a very high rating. These results indicate that the e-book has an attractive visual appearance, material presentation, and language that are easy for students to understand. The positive student response to this interactive media indicates that e-books can effectively support the learning process (Yuberti, Komikesari, and Lubis, 2022). The use of interactive e-books can create an engaging, interactive, and easy-to-understand learning environment, making learning more enjoyable and effective.

Revision of Trial Results

After conducting an initial field trial to gather teacher and student feedback on the developed interactive e-book, the next step was to revise the initial field trial results based on the feedback and input obtained in the previous stage. Improvements were made by replacing the interactive evaluation questions with Adobe Flash Professional CS6, while the previous evaluation questions were created using the tools available in Flip PDF Professional. The evaluation questions before the revision were created by inserting images of standard reduction potential data for several electrodes, while the evaluation questions after the revision were created by entering the data directly into Adobe Flash Professional CS6.

Characteristics of an Interactive E-book Based on Chemical Representations

The developed e-book is an interactive e-book based on chemical representations of voltaic cells. It has the following characteristics: 1) the learning material is divided into six sub-topics: redox reactions, circuits and reactions in voltaic cells, voltaic cell notation, electrode potential, voltaic series, and practical applications of voltaic cells. This makes it easier for students to learn and understand voltaic cells gradually; 2) the developed e-book is in .exe format, so it can be used on a computer or laptop; 3) the developed e-book is informative and interactive multimedia and has an attractive appearance due to the combination of color and text; 4) the interactive e-book is complemented by discourse on everyday life and clear and attractive images. 5) Interactive e-books are equipped with an identification column that can be filled in by students to develop their knowledge from the results of observing a phenomenon or discourse and an explanation column that provides a conclusion to the answer; 6) Interactive e-books are equipped with interactive evaluation questions so that students can find out their ability to understand the voltaic cell material that has been studied and 7) The developed interactive e-books have three levels of chemical representation, namely macroscopic, submicroscopic, and symbolic. The presence of images, animations and videos based on chemical representations with

macroscopic, submicroscopic and symbolic levels helps students to more easily learn voltaic cell material or other chemical materials. The dominant chemical representation presented is a representation at the symbolic level.

Figure 1. Discourse in an interactive e-book

Figure 2. Macroscopic level of interactive e-book

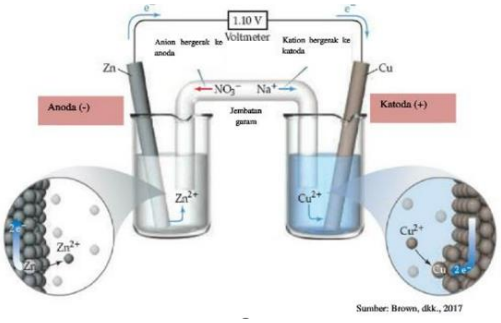

Figure 3. Submicroscopic level of an interactive e-book.

Tabel 1. Potensial reduksi standar (E°) beberapa zat pada 25°C

Elektroda	Setengah-Reaksi		E° (V)
Li^+/Li	$Li^+ (aq) + e^-$	$\rightarrow Li (s)$	-3,04
K^+/K	$K^+ (aq) + e^-$	$\rightarrow K (s)$	-2,93
Ca^{2+}/Ca	$Ca^{2+} (aq) + 2e^-$	$\rightarrow Ca (s)$	-2,84
Na^+/Na	$Na^+ (aq) + e^-$	$\rightarrow Na (s)$	-2,71
Mg^{2+}/Mg	$Mg^{2+} (aq) + 2e^-$	$\rightarrow Mg (s)$	-2,36
Al^{3+}/Al	$Al^{3+} (aq) + 3e^-$	$\rightarrow Al (s)$	-1,66
H_2O/H_2	**$2H_2O (l) + 2e^-$**	**$\rightarrow H_2 (g) + 2OH^- (aq)$**	**-0,83**
Zn^{2+}/Zn	$Zn^{2+} (aq) + 2e^-$	$\rightarrow Zn (s)$	-0,76
Cr^{3+}/Cr	$Cr^{3+} (aq) + 3e^-$	$\rightarrow Cr (s)$	-0,74
Fe^{2+}/Fe	$Fe^{2+} (aq) + 2e^-$	$\rightarrow Fe (s)$	-0,44
Ni^{2+}/Ni	$Ni^{2+} (aq) + 2e^-$	$\rightarrow Ni (s)$	-0,40
Sn^{2+}/Sn	$Sn^{2+} (aq) + 2e^-$	$\rightarrow Sn (s)$	-0,14
H^+/H_2	**$2H^+ (aq) + 2e^-$**	**$\rightarrow H_2 (g)$**	**0**
Cu^{2+}/Cu	$Cu^{2+} (aq) + 2e^-$	$\rightarrow Cu (s)$	+0,34
O_2/OH^-	**$O_2 (g) + 2H_2O (l) + 4e^-$**	**$\rightarrow 4 OH^- (aq)$**	**+0,40**
I_2/I^-	$I_2 (s) + 2e^-$	$\rightarrow 2I^- (aq)$	+0,54
Fe^{3+}/Fe^{2+}	$Fe^{3+} (aq) + e^-$	$\rightarrow Fe^{2+} (aq)$	+0,77
Hg^{2+}/Hg	$Hg^{2+} (aq) + 2e^-$	$\rightarrow Hg (l)$	+0,79
Ag^+/Ag	$Ag^+ (aq) + e^-$	$\rightarrow Ag (s)$	+0,80
Br_2/Br^-	$Br_2 (l) + 2e^-$	$\rightarrow 2Br^- (aq)$	+1,07
O_2/H_2O	**$O_2 (g) + 4H^+ (aq) + 4e^-$**	**$\rightarrow 2H_2O (l)$**	**+1,23**
Cl_2/Cl^-	$Cl_2 (g) + 2e^-$	$\rightarrow 2Cl^- (aq)$	+1,36
Au^{3+}/Au	$Au^{3+} (aq) + 3e^-$	$\rightarrow Au (s)$	+1,52
F_2/F^-	$F_2 (g) + 2e^-$	$\rightarrow 2F^- (aq)$	+2,87

Sumber: Petrucci, 2007

Fugure 19. Symbolic level in interactive e-book

▪ CONCLUSION

Based on the research results and discussion, it can be concluded that 1) the characteristics of an interactive e-book based on chemical representations on voltaic cell material begin with a discourse related to phenomena in everyday life accompanied by images and videos based on chemical representations, equipped with identification columns, explanation columns, and interactive evaluation questions, 2) expert validation includes aspects of content suitability, construction, and readability that have very high criteria, so it is said to be valid and feasible, 3) teacher responses include aspects of content suitability, construction, and readability that have very high criteria, and 4) student responses include aspects of interestingness and readability that have very high criteria.

This part is written in paragraph form (not in the form of points or numbers). The conclusion must be written concise (briefly and clearly). It should not re-discuss the research results. The conclusion must be able to answer the research objectives/questions and should not repeat the abstract or simply rewrite the experimental results. This part should reflect the innovation or improvement of the existing science. Some suggestions related to the results could be added into.

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