



Voltaic Cell Practical Guide Application Based on Mobile-Augmented Reality to Improve Student's Understanding Concepts

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Abstract: This study aims to analyze the practicality, feasibility, and effectiveness of learning media as an augmented reality-based practicum guide application for students' conceptual understanding of voltaic cells. The application development used the Thiagarajan development method with the 4-D model (Define, Design, Develop, Disseminate), but it was sufficiently developed to be 3-D. A limited trial with seventeen Al-Falah Senior High School students was conducted in August 2021 on students who had been given voltaic cell material. Pretest-posttest sheets, validation-review sheets, and student response questionnaires were used as research instruments. The data analysis technique used quantitative description. Pretest and posttest results were analyzed based on normality, paired sample test, and N-gain. The results of this study indicated that the developed application could improve students' understanding of concepts. The application validation results obtained a content validation score of 94%, a construct validation score of 86%, a presentation-related validation score of 96%, and a language-related validation score of 90%, indicating that it was very valid. The application was practical because the average percentage of responses was 92%. Based on the t-test with a significance value of 5% that yielded the Sig value, the application was reported to be very effective. 0.00 0.05 (2-tailed) and an N-gain analysis score of $0.83 > 0.7$.

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Introduction

Chemistry is a branch of natural science that integrates concrete and abstract concepts in teaching (Susanti et al., 2018). The chemistry concept has three dimensions: macroscopic, microscopic, and symbolic. Electrochemistry, which studies the movement of electrons in an electrical medium (electrode), is one of the chemical materials with macroscopic, microscopic, and symbolic concepts. Electrochemistry is founded on reduction-oxidation (redox) reactions and electrolyte solutions (Tewal et al., 2021). Electrochemistry is generally subdivided into three concepts: redox reactions, voltaic cells, and electrolytic cells (Rokhim et al., 2020). Students have difficulty learning electrochemical material because of the microscopic aspects that occur in the events of releasing and capturing electrons in redox reactions. Students studying the voltaic cell sub-material have been unable to understand the material's meaning and concept and instead tend to memorize it (Sukmawati, 2019). The Voltaic cell material has many conceptual errors, and students find this topic difficult to understand (Email et al., 2019). High school students in Indonesia and Japan have only 40% understanding of electrochemical materials (Sukmawati, 2019).



Each type of learning necessitates a strategy, method, and learning media that can give students a positive impression of learning activities. For example, in the case of science learning, almost all material necessitates experimental activities to support the achievement of learning objectives. Because of a lack of teacher awareness about the importance of doing practicums, as well as a lack of availability of tools and materials needed for practicums, not all schools can carry out practicums, resulting in students lacking the expected experience and knowledge (Agustina et al., 2021; Sumarti et al., 2018). The role of the teacher continues to dominate learning activities. Students only listen to the teacher's explanation and are only concerned with the accuracy of the material rather than with the importance of student participation. As a result, students can only memorize concepts without fully understanding them, resulting in low conceptual understanding (Fitriyah et al., 2020).

To ensure that students fully comprehend the concept of a voltaic cell from real experiments that can be overcome with other types of experiments that can be operated by each student in the form of virtual experiments, educational innovation in the form of media utilization is one effort that needs to be made. A computer-controlled virtual practicum is presented in the virtual experiment. The state of educational technology today can be used to raise the standard of instruction in classrooms. Interactive multimedia can be used to teach chemistry and enhance students' cognitive abilities (Rusmansyah et al., 2023; Winatha & Abubakar, 2018). Based on research conducted by Fitriyah et al. (2020), Augmented Reality (AR) technology integrated into learning medicine combines three-dimensional virtual world objects into a real three-dimensional environment will improve concept understanding in learning because the media used is attractive. Using an Augmented Reality technology-based practicum guide equipped with a marker that will display 3D objects on the material is one way to use technology to support the practicum-based student learning process if we have issues with limited practicum needs (Behmke et al., 2018). It allows us to project material realistically and involve all five senses' interaction. Mobile learning can be used to manage the use of applications. Because M-Learning uses technology frequently used in daily life, it has the flexibility of usage time, the portability of the device, and the ability to engage many users and students. Students can use this application by simply downloading it and using it online anywhere and anytime (Mirfan, 2018; Pradani et al., 2020; Sepriandi & Dirgantara, 2019).

In light of the context, as mentioned earlier, the researcher hopes to create Augmented Reality-based learning materials that are both useful and consistent with the fundamentals of education to improve students' comprehension of chemistry instruction in general and the Volta cell material. By using this application, students will be interested and can easily understand the concept of a voltaic cell because it can display a three-dimensional (3D) representation of the events of releasing and capturing electrons in redox reactions.

Research Method

This research used a development research method with the design of the 4-D model (Define, Design, Develop, and Disseminate), but it was sufficiently developed to be 3-D. Research and development is a method that creates a product by evaluating its efficacy (Sugiyono, 2016).

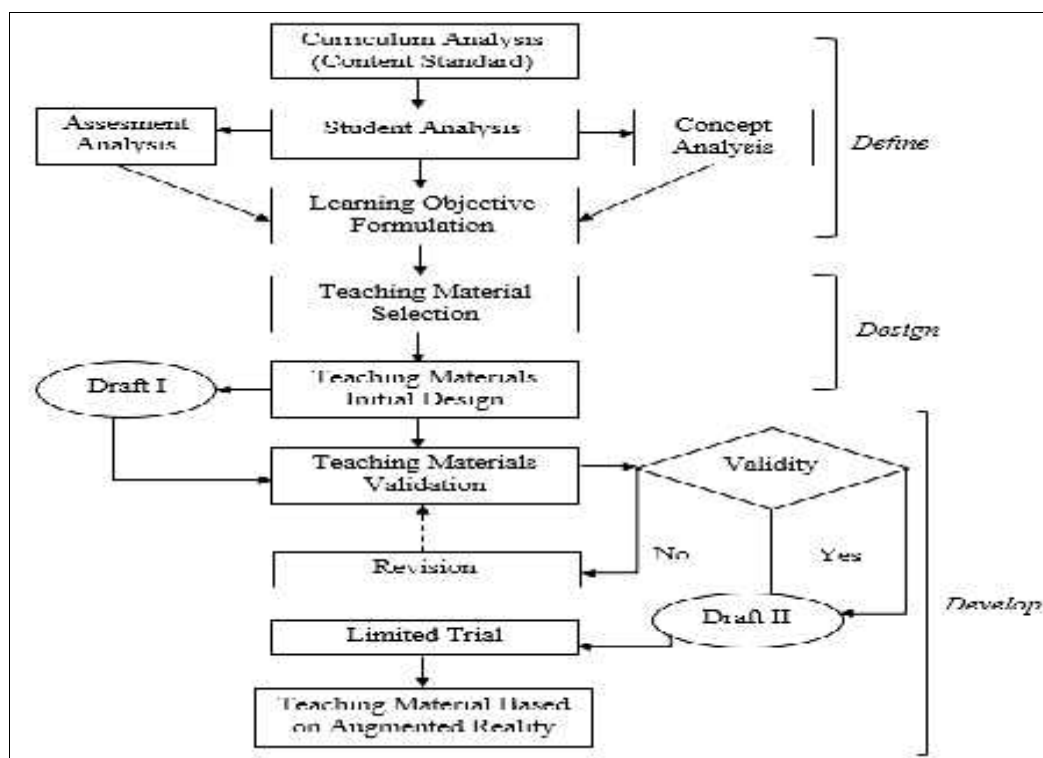


Figure 1. 4-D Model

Seventeen students who had received chemical material related to the voltaic cell factor were the research subjects in this study, conducted in August 2021 at Al-Falah High School in Surabaya. The findings of this study's data were quantitative and based on validity, applicability, and efficacy results. The research tools used included pretest, posttest analysis and evaluation skills sheets, validation sheets, review sheets, and student response questionnaires.

In order to get a qualitative evaluation of the critiques and recommendations from lecturers as a guide for improving the application, a review of the augmented reality-based practicum guide was conducted. Two lecturers from the Department of Chemistry, Faculty of Mathematics and Natural Sciences, Unesa, and one chemistry teacher from Al-Falah High School validated the augmented reality-based practicum guide application regarding content and construct validity. Students completed an open-ended and closed-ended response questionnaire and provided information about the application's practicality. The outcomes of the pretest and posttest understanding of the concept of voltaic cell material were used to determine the effectiveness of the application. In order to analyze the data validation results, a quantitative descriptive method was used. The results were expressed as a percentage that was derived from the calculation of the assessment score criteria. A Likert scale is used to calculate this result.

Table 1. Likert Scale

Score	Criteria
1	Not Good
2	Less Good
3	Enough
4	Good
5	Very Good



The percentage was calculated by comparing the validator data collection's overall score to its highest possible score. The formula: can be used to calculate percentages.

$$\text{Total score} = (\text{Sum of score results: Score criteria}) \times 100\%$$

The highest score, the number of respondents, and the number of questions were combined to create the criterion score. With the percentages obtained being interpreted in the evaluation based on Table 2, the results of this validation are used as a reference to establish the application eligibility in terms of validity.

Table 2. Interpretation of the Validity of Each Criterion

Percentage (%)	Criteria
0 – 20	Very poor
21 – 40	Less
41 – 60	Enough
61 – 80	Valid
81 – 100	Very valid

The application is deemed feasible with the following content eligibility criteria, as determined by the percentage of the criteria above: (1) the feasibility of the content of the material; (2) the accuracy of the material in the application; (3) the updating of the questions and material in the application; and (4) the suitability of the application with the dimensions of the skills trained (understanding of the concept). The application's characteristics, the skills in the application characteristics, the presentation and graphics components, and the linguistic components make up the construct's feasibility criteria. The developed augmented reality-based practicum guide application has very valid criteria if the percentage of research findings is 81%.

Students who had been evaluated for the application's usability filled out a response questionnaire to help determine how practical the application was. The percentage of student response data from the questionnaire was examined based on the Guttman scale. The Guttman Scale measurements are performed to obtain a definitive "yes" or "no" response. Scores of "1" indicate "yes," while "2" indicates "no" (Sugiyono, 2016). Table 3 of the Guttman scale is shown below.

Table 3. Guttman Scale

Evaluation	Scale Value
Yes	1
No	0

The results of the student response questionnaire were then quantitatively and descriptively analyzed as a percentage of the data from the Guttman Scale using the following formula:

$$\text{Total score} = (\text{Sum of score results: Score criteria}) \times 100\%$$

The following table explains how the percentages obtained are interpreted using five response criteria.

Table 4. Interpretation of the Response of Each Criterion

Percentage (%)	Criteria
0 – 20	Not practical
21 – 40	Less practical
41 – 60	Practical enough
61 – 80	Practical
81 – 100	Very practical



If the percentage of research findings is less than 81%, the application's developed criteria are advantageous. The pretest-posttest-test sheet is used to determine the application's effectiveness. The initial test sheet, or pretest, can be used to determine students' initial abilities, and the final test sheet, or posttest, can be used to determine students' understanding abilities. The test sheet used includes a description of the skills domain as well as questions from the knowledge domain that are multiple choice. The following calculations were used in the descriptive and quantitative analysis of student-test result data using N-gain scores.

$$(g) = \frac{[\%(Sf)] - \%(Si)}{[100\% - \%(Si)]}$$

Information:

(g) : increase in learning outcomes

(Si) : mean pretest value

(Sf) : mean posttest value

The results of the score calculation (g) are interpreted in the range of values according to the category.

Table 5. N-Gain Score Interpretation Criteria

Value Range	Criteria
G 0,7	High
0,3 G 0,7	Medium
G < 0,7	Low

Based on these criteria, the application is declared effective if an increase in the N-gain score is obtained 0.7 which is included in the high category.

Results and Discussion

In order to improve understanding of chemical concepts, research is done to assess the validity, viability, and efficacy of augmented reality-based practicum guide applications. The practicum Guide application is a breakthrough in educational technology that helps students learn concepts more thoroughly to work continuously and intently. The purpose of creating practicum guides is to help participants develop their understanding and skills through the activities in the guide's activities (Almubarak et al., 2021). It highlights the significance of developing practicum guides. To achieve learning objectives, the practicum guide application was created to facilitate teaching and learning activities in the laboratory. Visualize microscopic ideas made possible by three-dimensional augmented reality applications. According to the theory, augmented reality learning materials can improve students' comprehension of submicroscopic ideas (Rizqullah & Lutfi, 2021).

The 4-D Thiagarajan model (Define, Design, Develop, and Disseminate), which only applies to the Develop stage, was used to conduct this research using the R&D method. The research's product development took the form of learning applications. It is hoped that this learning application, which is based on Augmented Reality, will be used in the chemistry learning process for voltaic cells after being evaluated by two chemistry lecturers and one chemistry teacher.

Definition Stage

At this point in the definition process, it can be determined that the material for voltaic cells is found in the fundamental skills of 3.4 (analyzing the functions of voltaic cells and describing how they work) and 4.4 (creating voltaic cells out of materials found in the environment). The concepts explored in this study were built upon the fundamental skills, encompassing various aspects such as defining the voltaic cell, identifying its inventor,



understanding its components, comprehending its functionality, analyzing cell notation, evaluating cell potential, examining electrode potential, studying the electrode activity series, investigating reaction spontaneity, and exploring the practical applications of voltaic cells in everyday life. Additionally, interviews with the chemistry teachers at Al-Falaah High School were conducted during the preliminary stage, and it was discovered that the school was unable to conduct practicums due to a lack of tools and materials required for practicums, making it challenging to meet the learning objectives in experimental activities.

Students may have an alternative for understanding the material: using learning media. Augmented reality in educational activities improves students' ability to find information, presents accurate simulations, and fosters literacy. As a result, there may be an increase in student learning activities and learning completion (Hakim, 2018). Using communication technology in learning is very helpful for creating innovations in education and training (Irwansyah et al., 2019). Teaching materials can be provided using media (Wahid et al., 2017). Students can study independently using this application with or without direct teacher supervision. Applications are user-friendly, self-contained, and adaptive, encouraging students' independent learning (Harwanto et al., 2019).

Design Stage

The links https://bit.ly/AR_SelVolta for the voltaic cell practicum and <https://bit.ly/VoltaicCellApplication> for the voltaic cell practicum guides allow access to this application. Both teachers and students can access it online, but the teacher must first register before using the program. Google's widely used email can be used for registration. After successfully creating an account, teachers and students can use the developed applications.

The Voltaic Cell application has been designed to be an Augmented Reality-based learning application for Android with a size of 22.1 Mb. Smartphones meeting the requirements for Android version 12 minimum can use the Voltaic Cell app. This application includes Voltaic cell animation, practice questions, and their solutions in addition to the available content. The developed application has several benefits, including being available online, being simple to use, and having many intriguing features. There are also many different questions, such as description and multiple-choice. Students completed answers were automatically sent to the teacher's account and email, where they can either be manually or automatically revised. Students can scroll down while working on the questions to view the application's contents and parts, making it easier to use (Dwi & Kusuma, 2018).

White and yellow were chosen as the application design colors in the media design stage. White can be used with high curiosity and intelligence based on logic, cooperation, and integrity. Happiness, enthusiasm, and cheer are all connoted by the color yellow. It is hoped that students will increase their intelligence, trust, and integrity while applying their learning using this application.

Applications for learning based on augmented reality are created using the primary Android Studio and Unity software and several other auxiliary programs like Vuforia, Adobe XD, and Blender 3D. Creating supporting materials, such as layout designs, content, and 3D illustrations of a series of voltaic cell practicums, as shown in Figure 2 and Figure 3, is the first step in creating an augmented reality-based learning application.

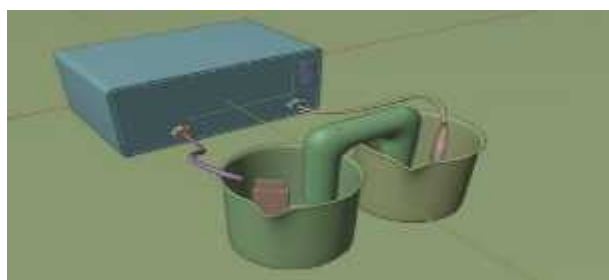




Figure 2. Voltaic Cell Practicum Series in 3D Illustration with Blender



Figure 3. Voltaic Cell Practicum Series in 3D Illustration with Vuforia

Students' attention, interest, self-confidence, interest, motivation to learn, and satisfaction can all be increased by presenting 3D images in Augmented Reality media. It is consistent with a study by (Kusdiana et al., 2019) that found that augmented reality learning media can improve students' cognitive, learning interest, and affective skills and turn abstract learning into concrete learning through visualization of 3D pictures. The next stage was the creation of the practicum guide application's components, which include media display formats like user profile menus, developer profiles, main menus, virtual laboratories that contain several Volta cell practicum tools, animations, question creation, and answer keys. It aims to develop a format and elaborate on the subject matter for discussion in educational applications—storyboard or first draft, as shown in Table 6 below.

Table 6. Draft of a Mobile Augmented Reality Practicum Application

No.	Pictures and Descriptions	No.	Pictures and Descriptions
1.	 <p>Splash Screen and Menu</p> <p>There are several main menus, namely laboratory safety, hazardous materials, laboratory tools, practical instructions, materials, exercises, and additional menus, namely the homepage, camera, and assignments.</p>	2.	 <p>Discussion Menu</p> <p>The discussion menu contains discussion questions and discussions related to practicum and the evaluation menu contains questions that students must work on after doing practicum and there is a score that appears after doing it.</p>



2.



Evaluation Menu and Answer Key

Contains practice questions that train student understanding, there are 10 questions complete with a recap of the points obtained after answering the practice questions and answer keys.

3.



Laboratory Safety Menu

Contains various laboratory safety symbols along with a brief explanation of these symbols.

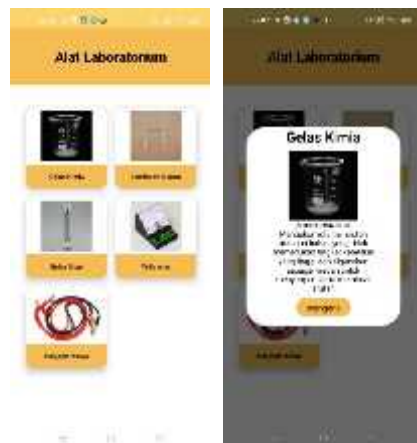
4.



Hazardous Chemicals Menu

Contains various symbols of hazardous chemicals along with a brief explanation of these symbols.

5.



Practicum Tools Menu

Contains the kinds of tools used when practicum voltaic cells along with a brief explanation of the symbols.

6.



Material Menu

Contains voltaic cell materials and comes

7.



Practical Guide Menu and Augmented Reality Volta Cell Series

with easy-to-understand explanations

8.



User and Developer Profile Menu Contains user data such as the percentage of discussion and evaluation work. As well as app description and developer profile identity

9.



Augmented Reality

Contains 3D illustrations of a series of voltaic cell practicum tools along with 3D illustrations of molecular level reactions.

Development Stage

One Al-Falah High School teacher in Surabaya and two chemistry lecturers at FMIPA Unesa carried out the content and construct validation process during the development stage. The content validation criteria were as follows: (1) content feasibility of material coverage, (2) accuracy of the material, (3) current questions and material, and (4) compatibility with the dimensions of the skills being trained (concept understanding). The following are the eligibility requirements for construct validation: (1) character traits, (2) skill traits, (3) presentation and graphic components, and (4) language components. The validation procedure uses a validation tool, and the validation results are as follows.

Table 7. Validation Result

Component	Percentage (%)	Criteria
Contents	94	Very valid
Construct	86	Very valid
Presentation	96	Very valid
Language	90	Very valid

The content feasibility results from the recapitulation data of the validation results showed that the scope of eligibility for the content contained in the application followed the Basic Competency of the voltaic cell and the dimensions of understanding the concept, with valid criteria of 94%. The four components of application content that make up its viability are (1) the content's viability; (2) the application's accuracy; (3) the application's most recent questions and materials; and (4) the application's suitability for the dimensions of the skills being trained (concept understanding) (BSNP, 2014).

The goal of construct validity is to determine whether the substances used in the application and the indicators of conceptual understanding are appropriate. The percentage of



the construct application's feasibility with very valid criteria was 86%, according to the recapitulation table of the validation results.

The application demonstrates a diverse range of comprehension concepts, such as interpretation and illustration, through examples, classification, inference drawing, comparison, and explanation (Fitriya & Mitarlis, 2020; Kartikaningsih et al., 2021; Sonia et al., 2021). A critical component of learning is identifying the concept's understanding indicators. Understanding the idea is also a crucial first step in finding solutions to problems that arise in daily life. With very valid criteria, the validity of the developed application presentation receives a percentage of 96%. It declares that the end product is an interactive, systematic, and coherent learning tool. Four elements—supporting the presentation of material, presentation techniques, completeness of presentation, and learning presentation—are relevant to the validity of presenting an application.

Students very well use the language structure of the application as a learning medium because language is an essential key in chemistry subjects that can affect students' success in understanding learning of chemical material. The linguistic validity of the application with very valid criteria obtained a percentage of 90%, so it can be stated that students very well use the language structure of the application as a learning medium. The developed application's language requirements are as follows: (1) suitability for development, (2) motivational aptitude, (3) coherence and coherence of language, and (4) readability.

The application was tested in the following stage by seventeen students who had taken chemistry classes at Al Falah Senior High School that included voltaic cells. A practicality questionnaire based on student responses and observations of student behavior during a Zoom Meeting led by two students served as the trial's output. This response questionnaire relates to (1) knowing the content's clarity and its relationship to improving students' understanding; (2) knowing students' interest in the application; (3) knowing the application's language's clarity; and (4) determining the degree of application usability (graphic). Give an example of the typical student response as follows:

Table 8. Results of the Response Questionnaire

Component	Percentage (%)	Criteria
Contents	93	Very practical
Construct	93	Very practical
Language	94	Very practical
Chart	88	Very practical

The practicality of the application was determined by the recapitulation table data from the response questionnaire results, with an overall average of 92% and a percentage of 81% for each component. It demonstrates how useful the application that was created is.

The effectiveness testing stage follows when cognitive and skills tests were administered as part of pre-and post-test sheet instruments. There are 12 questions (analyze (C4), evaluate (C5)) related to voltaic cell material in the cognitive test, which consists of multiple-choice questions with five possible answers. There are seven questions related to practical skills in the form of questions, especially descriptions, on the skills test (analyzing (C4), evaluating (C5)) (Noviana et al., 2019).

Table 9. Normality Test of Shapiro Wilk

	Statistic	dF	Sig.
Pre-test	0,975	17	0,896



Post-test	0,965	17	0,718
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The IBM SPSS Statistics 26 program was used to conduct the normality test. Data 9 from the table indicates the results. According to the normality test, the sig. value for the pretest was 0.896, and for the posttest, it was 0.608. Based on these findings, the Shapiro-Wilk test revealed that both the pretest and posttest values followed a normal distribution, as the sig. value was greater than 0.05 (Hulu & Sinaga, 2019). Subsequently, a t-test was performed using the results of the normality test. If there is a significant difference between the pretest and posttest, the t-test will detect it.

Table 10. Result of Paired Samples Test

	Mean	Std. Deviation	Std. Error Mean	t	dF	Sig. (2-tailed)
Pretest-Posttest	-42,77412	18,08620	4,38655	-9,751	16	0,000

According to Table 10. t-test, Sig. (2-tailed) 0.05, there was a significant difference between the pretest and posttest results. The result was that Ho was rejected while Ha could be accepted. Ho claimed that the pretest-posttest revealed no significant changes or differences. Ha, meanwhile, claimed that the pretest-posttest revealed significant alterations or differences. The application created was said to be very effective in boosting conceptual understanding of voltaic cell material based on the findings of the t-test analysis (Rizkihati et al., 2019)

Table 11. N-Gain Score

Pretest (%)	Posttest (%)	N-Gain	Criteria
48,52	91,29	0,83	Tinggi

According to Table 11. To analyze the pretest and posttest results, determine the N-Gain score. The outcomes demonstrate a high criterion with a score of 0.83, which indicates that the n-gain score is less than 0.7. Based on this, the application created during the development process helps teach students to think critically and analytically.

Learning applications based on augmented reality are visual-based media that serve as learning resources during the teaching and learning process and are anticipated to improve the learning environment. Learning media can create new desires and interests, boost motivation for learning activities, and even psychologically impact students during the teaching and learning process. It shares the same belief that learning media, particularly visual media, can capture students' interest and attention to get them to focus on the subject at hand (Affriyenni et al., 2020). The possibility of achieving learning objectives is significantly increased by the presence of this interest (Hasibuan et al., 2022; Sofiudin et al., 2019)

Conclusion

The validity scores for applications created using the 3-D model (Define, Design, Develop) were 94% for content validation, 86% for construct validation, 96% for presentation validation, and 90% for linguistic validation, making them very valid. The student response score of 92% indicated that the application was beneficial. The t-test results that produced the Sig value indicated that the application was effective. N-gain score of 0.83 and two-tailed 0.00 0.05. Consequently, the resulting application can be utilized as a teaching tool to help students better understand the idea of voltaic cell material.



Recommendation

Based on the results of this study, there are various suggestions as follows: 1) For teachers, the practicum guide application developed can be a learning option, especially to improve students' understanding of concepts. 2) For students, the practicum guide application developed can be a medium for independent study either at school or at home. 3) For schools, learning using the help of practicum guide applications can be one way to improve the quality of students at school, especially in increasing their understanding of concepts.

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