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Development of Interactive Learning Media Based on a 2-Dimensional Virtual Laboratory on Electrochemical Materials

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Abstract
This study aims to analyze the feasibility of interactive learning media based on a 2D virtual laboratory for electrochemistry material and to examine students' responses to its use. The media was designed as a solution to address the limitations of laboratory equipment and materials often encountered in schools. The research method employed was Research and Development (R&D) using the ADDIE development model (Analysis, Design, Development, Implementation, Evaluation). The media's validity was analyzed using Aiken's V content validity, involving three expert validators. The results of the analysis indicated a validity score of 0.86, which falls into the high category, demonstrating that the media is feasible for use. Student responses to the media were also analyzed, yielding an overall quality percentage of 75.98%, classified as good. Based on these findings, the learning media is considered effective and applicable in the teaching and learning process for electrochemistry materials to enhance students' conceptual understanding and practical skills.

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INTRODUCTION

The rapid development of science and technology demands changes in various fields, including education. Currently, the world has entered the industrial era 5.0, which emphasizes the integration of humans with technology to create a balance between technological progress and human sustainability (Ria and Wahidy, 2020). In the context of education, the use of technology in learning is a solution to various challenges, especially in chemistry practicums which often face limited laboratory facilities. By integrating technology as an interactive learning medium, educators can improve students' learning experiences in understanding abstract concepts, such as electrochemistry (Lin et al., 2017).

Interactive learning media allows students to learn actively and independently through operational control in the learning process (Hermansyah et al., 2015). Practicums in science education are very important to deepen understanding of concepts, but their implementation is often hampered by limited tools, materials, and laboratory facilities (Hikmah et al., 2017). This obstacle causes minimal student experience in understanding concepts in depth. Therefore, virtual laboratories are present as an alternative to replace real laboratories, especially for schools that do not have adequate facilities and infrastructure (Ilahi et al., 2022). Several studies have shown that virtual laboratories can improve students' understanding in science learning, especially in abstract materials that require visualization, such as electrochemistry. Ikhsan et al (2020) stated that virtual laboratories can strengthen students' understanding as a substitute for real practicums, because they allow experiments to be carried out repeatedly without time and material limitations.

Virtual laboratories are learning innovations that can be applied efficiently on various devices, including smartphones. This media is designed as an alternative to complement or replace practicums that cannot be carried out directly in the laboratory due to certain limitations (Fauziah et al., 2024). With interactive visualization, abstract concepts such as electrochemistry can be explained more clearly, thereby improving student understanding. Electrochemistry includes the concepts of voltaic cells, corrosion, and Faraday's law, which are known as materials with a high level of analysis because they require deep conceptual understanding and complex mathematical calculations (Syahira et al., 2020). The use of interactive learning media based on virtual laboratories and 2-dimensional animations in electrochemistry material has been shown to improve student understanding. An attractive appearance, combined with 2-dimensional animation, can increase students' interest in learning, so that they are more focused on following the learning process. This is in line with research by Hikmah et al (2017) which states that virtual laboratories can improve conceptual understanding and attract students' interest, because this media is designed in an attractive way and allows students to focus more on understanding ongoing practicum activities.

Many students have difficulty understanding electrochemistry because it is abstract and requires submicroscopic representations to explain the phenomena that occur (Sari, 2021). Concepts such as the role of salt bridges, oxidation-reduction reactions, and electron flow often lead to misconceptions (Sutantri, 2022). 2D virtual laboratory-based visualization has been shown to be effective in helping students understand electrochemical concepts comprehensively, both at the macroscopic and microscopic levels (Puspayanti et al., 2023). In addition, this simulation is able to replicate real laboratory conditions, allowing students to conduct experiments that were previously difficult or even impossible due to logistical limitations (Mashani et al., 2024). The use of innovative technologies such as virtual laboratory simulations can also be an alternative to replace direct experiments in real laboratories, especially in conditions where limited tools and materials are the main obstacles (Yulis and Fauziah, 2024)

At SMAN 10 Kendari, the limited tools and materials for practical work cause electrochemistry learning to only be done theoretically without any practical support. Teachers often direct students to watch videos on YouTube as an alternative learning method. However, this method has not been able to provide optimal direct experience, so many students still have difficulty understanding the concept of electrochemistry, especially in calculating cell potential and describing voltaic cell reactions.

This study aims to analyze the feasibility of interactive learning media based on 2-dimensional virtual laboratories on electrochemistry material. Unlike previous studies, this study uses Adobe Animate, which is more interactive and easily accessible to students because it is offline. In addition, this study also aims to determine students' responses to the use of this media. By utilizing Adobe Animate, this media is expected to provide more interactive and interesting electrochemical experiment simulations. Adobe Animate was chosen because it has complete features that support the development of learning multimedia (Wibawanto, 2018). This study offers an innovative solution to improve the quality of electrochemistry learning at SMAN 10 Kendari, so that it can help students understand electrochemistry concepts more deeply and overcome obstacles in implementing practicums.

RESEARCH METHODS

This study uses the Research and Development (R&D) method to produce products in the form of interactive learning media. This study uses the ADDIE development model, developed by

Robert Maribe Branch. The ADDIE development model consists of five stages, namely: Analysis, Design, Development, Implementation and Evaluation (Purba et al., 2024). This model was chosen because it has systematic stages in developing teaching materials. This study was conducted in November-December 2024 at Halu Oleo University, at the response test stage it was carried out at SMAN 10 Kendari.

The research subjects included validators consisting of material experts, media experts, chemistry teachers, and students of class XII MIPA 1 SMAN 10 Kendari. Material experts and media experts are lecturers from the Chemistry Education Department of Halu Oleo University who have competence in their fields. Chemistry teachers of SMAN 10 Kendari act as additional validators. Meanwhile, students of class XII MIPA 1 were selected because they are studying electrochemistry material and practicums, so they have relevant knowledge background.

The development procedure uses the ADDIE model which consists of the following five stages:

1. Analysis: Conducting a needs analysis to identify the needs of teachers and students regarding learning media, as well as analyzing the curriculum and student characteristics.
2. Design: Creating initial designs for learning media including storyboards, flowcharts, and research instruments such as feasibility assessment questionnaires.
3. Development: Developing the initial product which includes the creation of materials, images, and illustrations, as well as layout arrangement. This product is then validated by material experts and media experts using a questionnaire compiled based on the Likert scale.
4. Implementation: Testing the product in class XII MIPA 1 and collecting student response data through a questionnaire. The assessment results are used to determine student responses related to the virtual electrochemistry laboratory media.
5. Evaluation: Evaluation is the final stage in a learning process that aims to assess the effectiveness of a learning media. However, this research was only conducted up to the implementation stage. This limitation is based on the consideration that the steps that have been taken are sufficient to answer the formulation of the research problem. In addition, the limitations of manpower, costs, time, and the researcher's ability are also the reasons for this limitation. The limitation of these research steps is supported by Wina's opinion (2006), which states that research steps can be simplified without reducing the essence of research and its development.

The analysis technique used in this study uses descriptive statistical analysis.

Validity Test

The validity of the learning media was assessed using Aiken's V analysis. The validity coefficient was calculated using the formula:

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

$$S = R - Lo$$

The explanation of Aiken's validity coefficient formula is:
V = Aiken's Index
S = The score given by the rater minus the lowest score
R = The score given by the rater
Lo = Lowest rater score (1)
C = Highest rater score (4)
n = number of raters

Table 1. Validity Categories Based on Aiken's

Aiken's Range of Values V (V)	Validity Category
V < 0,4	Low
0,4 ≤ V < 0,8	Currently
V ≥ 0,8	Tall

(Utami et.al., 2024)

Student Response Questionnaire

Student responses were analyzed by calculating the average score using the formula:

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

While, $\bar{X}$ = Average score of all aspects or each aspect; $\sum X$ = The sum of the scores for all aspects or each aspect; n = Number of reviewers or students

Next, the average scores are categorized based on Table 2:

Table 2. Ideal Assessment Category Guidelines

No	Kategori	Rentang Skor ($\bar{X}$)
1	Very good (VG)	$\bar{X} > X_i + 1{,}8Sb_i$
2	Good (G)	$X_i + 0{,}6Sb_i < \bar{X} \leq X_i + 1{,}8Sb_i$
3	Enough (E)	$X_i - 0{,}6Sb_i < \bar{X} \leq X_i + 0{,}6Sb_i$
4	Less (L)	$X_i - 1{,}8Sb_i < \bar{X} \leq X_i - 0{,}6Sb_i$
5	Very less (VL)	$\bar{X} \leq X_i - 1{,}8Sb_i$

(Putri dan Arianingrum., 2024)

Description:
$\bar{X}$ = Average final score
X_i = The ideal average is calculated using the formula:
$X_i = \frac{1}{2}$(ideal highest score + ideal lowest score)
Sb_i = ideal standard deviation, calculated using the formula:
$Sb_i = \frac{1}{6}$(ideal highest score - ideal lowest score)
Ideal highest score = ∑ criteria item x highest score
Ideal lowest score = ∑ criteria item x lowest score

Calculate the percentage of ideal virtual laboratory quality using the following formula:

Ideal percentage = $\frac{average\ score}{ideal\ score}$ x 100%

RESULTS AND DISCUSSION

Virtual Laboratory-Based Media Development

This development stage, the flowchart, materials, storyboards that have been prepared, are then developed into media. To develop interactive learning media based on virtual laboratories, Adobe Animate 2020 software is used as the main software. Corel Draw 2020 and Microsoft Excel 2007 as supporting software. The following are the results of the development of interactive learning media based on virtual laboratories.

Initial Product Creation

Media creation begins with the creation of materials and continues with the inclusion of images,

animations, and navigation. The creation of interactive learning media based on virtual laboratories uses the Adobe Animate 2020 application because this application can create 2D animations needed in interactive learning media based on virtual laboratories that are being developed. The contents of the media that have been developed can be seen in Table 3.

Table 3. Contents of Interactive Learning Media Based on Virtual Laboratory

No	Menu	Description
1	Home Page	The main page loads the initial display when the media is first opened, starting with the display of the practicum title and the "Start" button to start the virtual laboratory application
2	User Profile	User Profile displays name and class for easy identification in virtual laboratory applications.
3	Main course	The main menu contains 5 menu options, namely: Instructions, Materials, Start Practicum, Settings, and Quiz.
4	Instruction	Instructions function to guide users in using the application, including navigation and understanding objects in the application
5	Material	The material serves as the main source of information to understand the concepts and theories that support the practicum. The material menu contains Basic Competencies (KD), Learning Objectives, Materials and Glossary
6	Start Practicum	Start Practicum provides interactive simulations of various electrochemical experiments, including standard electrode cell experiments, determination of E° voltaic cells, voltaic cell schemes, electrolysis cell work schemes, and electrolysis and metal plating experiments. Each test is designed to train practical skills safely, efficiently, and enjoyably
7	Arrangement	Settings function to adjust user choices such as setting music. There is music 1, music 2 and turn off music. And there is an "About" feature containing the developer profile of interactive learning media based on virtual laboratories
8	Quiz	The quiz contains questions related to electrochemistry material and explanations of the answers to the questions. The quiz contains 10 multiple choice questions and 10 true and false questions.

Media Suitability Test by Validator

The learning media that has been developed is first consulted with the supervising lecturer and then validated by the validator. Validation is carried out to request approval or suitability of the learning media to the needs of students so that the learning media is declared suitable for use in the learning process. The media is revised based on input from the supervising lecturer and examiner. Before the media is used by students, the media must first go through a validation process by validators, 2 chemistry education lecturers from Halu Oleo University and 1 chemistry teacher from SMAN 10 Kendari. The feasibility test by the validator on the virtual electrochemistry laboratory learning media aims to ensure that the learning media developed meets quality and effectiveness standards. The calculation of the validity of the contents of the virtual electrochemistry laboratory feasibility test statement using the Aiken formula from three (3) validators (assessors), namely lecturers (validator 1), lecturers (validator 2) and teachers (validator 3) who are experts in the field of material and media in each aspect can be seen in Table 4.

Table 4. Results of Feasibility Test by Validator

Statement	V	Category
Material Aspects in Learning Media		
Clarity of learning objectives	0,78	Currently
Learning objectives have no relevance to KI/KD/2013 Curriculum	0,67	Currently
The practical simulation is unclear and unsystematic	0,89	High
Suitability of material with KI/KD/2013 Curriculum	0,89	High
Learning media makes it easier for students to understand the material	1,00	High
Animation is not able to explain the concepts in the material	0,67	Currently
Suitability of the content of the material with the textbook for high school/equivalent level	1,00	High
Linguistic aspects		
The clarity and appropriateness of the language is difficult to understand, does not comply with EYD, and does not suit the intellectual development of students.	1,00	High
Language is not interactive and not communicative	0,89	High
Sentences and use of figurative words do not create double meanings	0,78	Currently
User convenience aspec		
Ease of understanding learning and interacting using Lab virtual learning media	0,78	Currently
Virtual labs cannot be used in the long term and do not save costs for purchasing chemicals.	0,89	High
Virtual labs cannot reduce the risk of accidents in the laboratory	0,89	High
Virtual labs reduce the use of chemicals and the chemical waste they generate.	0,78	Currently
Virtual lab can be operated on various devices such as laptops and smartphones.	0,89	High
Appearance		
The appearance of the virtual lab learning media design is not attractive	0,67	Currently
The fonts, sizes and colors in the virtual lab are inappropriate and unclear.	1,00	High
The illustrations displayed in the virtual chemistry laboratory media are clear	1,00	High
Placing illustrations on virtual lab learning media interferes with other components	0,89	High
The animation is clear so it can help students understand the flow of electrochemistry labs.	0,78	Currently
Features in the virtual laboratory cannot function properly	0,89	High
Average	**0,86**	High

Based on the results of the study conducted on measurements using Aiken, it was found that the results of the feasibility test by the validator showed a high validity value of 0.86. The calculation of the validation results can be seen more clearly in Appendix 2 (70-74). If the Aiken index is less than 0.4, it is said to be low validity, the Aiken index between 0.4-0.8 is said to have moderate validity and if it is more than 0.8 it is said to be high (Utami et al., 2024).

The calculation results show that all the content validity of each statement item is obtained more than 0.79, thus the statement items of the virtual laboratory learning media validity questionnaire have met the criteria. Overall, an average of 0.86 was obtained. The results obtained when associated with the results of the existing literature review have similarities, the validity carried out using Aiken has a high value so that it can be concluded that the use of Aiken provides a good level of validity and reliability (Ibrahim et al., 2020). Kurniawati (2021) revealed that the results of expert validation were then calculated using Aiken's V formula, which was known from the 21 items created, which meant they had a fairly high coefficient or good content validity and supported the content as a whole.

Product Revision

Researchers get various suggestions and input from validators. So researchers improve the virtual laboratory media developed by making revisions before the media is tested on students. The following revisions made by researchers are reviewed based on their aspects

Material aspects in learning media, the validity value that gets the medium category is in the clarity of learning objectives and the relevance of learning objectives with KI/KD/Curriculum 2013, so that the validator provides suggestions to follow KD that are adjusted to the learning objectives in the Basic Competencies of SMA/MA Ministry of Education and Culture 2013. Furthermore, in animations that are unable to explain the concept of the material, so the validator provides suggestions to add animations and materials related to redox material because before the revision the concept of redox was still lacking for students to learn. After improvements were made as attached to the revision results.

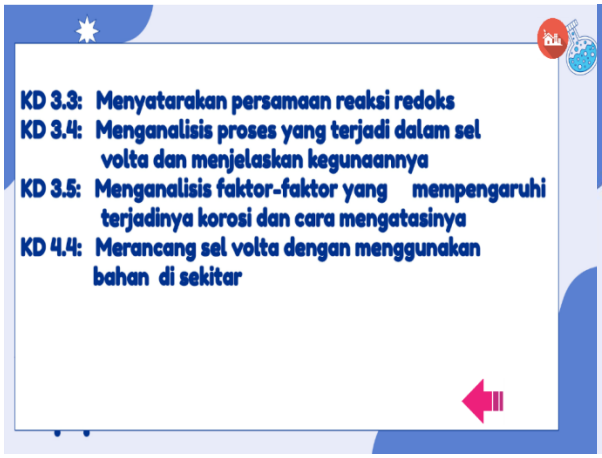
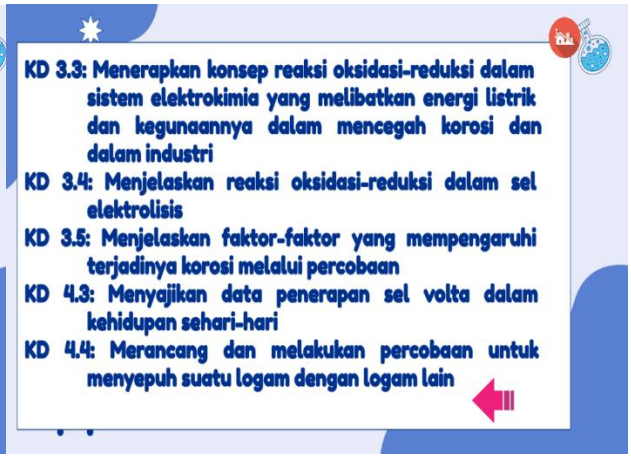
Before revision	After Revision
	

Figure 1. Basic Competencies in the Electrochemistry Virtual Laboratory before and after revision

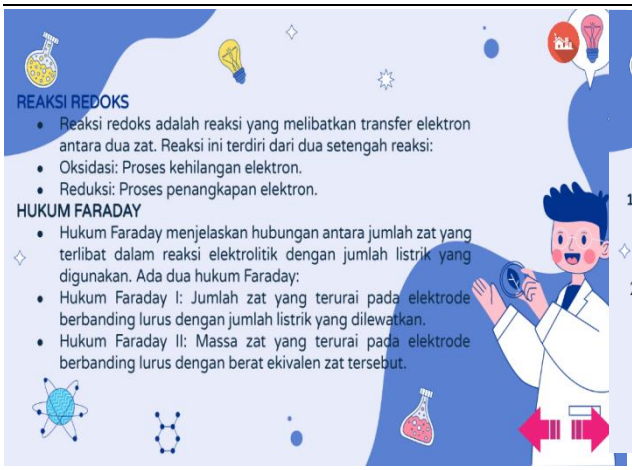
Before revision	After Revision
	

Figure 2. Redox material in the Electrochemistry virtual laboratory before and after revision.

Furthermore, in the animation that is unable to explain the concept of the material, so the validator provides suggestions to add animation and material related to the redox material because before the revision the redox concept was still lacking for students to learn. After the

improvements were made as attached to the revision results. The following is only the front view of the revision before and after.

Linguistic Aspect, the validity value that gets the medium category is in the fifth and the use of figurative words does not cause double meanings, so the validator provides suggestions to replace words so as not to cause double meanings, where here it is located in multiple choice question number 2, this change includes answer choices so as not to confuse students and improve the explanation to support better understanding. After making improvements as attached to the revision results.

Before revision	After Revision

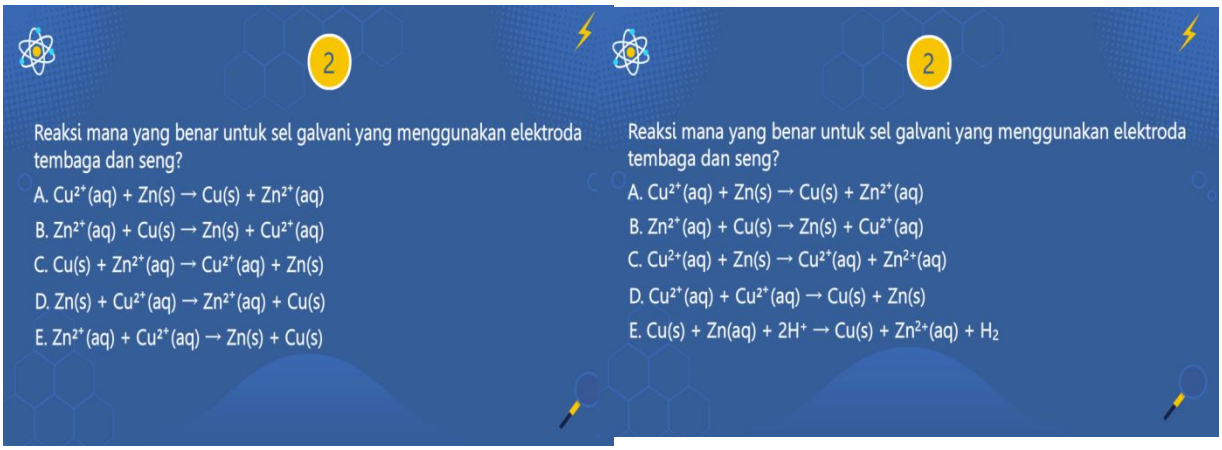


Figure 3. Multiple Choice Quiz Question number 2 in the Electrochemistry Virtual Laboratory before and after revision.

The aspect of user convenience, the validity value that gets the moderate category is the ease of understanding learning and interaction using virtual lab learning media and virtual lab can reduce the use of chemicals and chemical waste generated. Although the validator did not provide specific suggestions regarding improving the appearance, the validation results are classified as moderate. This assessment includes the ease of understanding learning materials and interacting with the features available in the application. However, these results need to be reviewed further because the learning media has been designed with clear instructions for use, including descriptions of the functions of the buttons and objects available in the application.

Display aspect, the validity value that gets the medium category is the display of the virtual lab learning media design which is not attractive and the animation is lacking so that it cannot help students understand the flow of the electrochemistry practicum. This shows that the design of the display media still needs improvement to increase visual appeal and effectiveness in students' understanding of the flow of the electrochemistry practicum. Although the validator did not provide specific suggestions regarding improvements to the display, the validation results are classified as moderate. Although the validator did not provide specific suggestions, the creator has improved the quality of the virtual laboratory media by combining more attractive colors and increasing the clarity of the text in the virtual laboratory application to high resolution (HD).

Product Response Test by Students

The product response test aims to determine students' responses to the developed virtual laboratory media. The product response test is carried out by implementing virtual laboratory media that has been validated and improved. The student response test was carried out in 29 students of class XII MIPA 1. The student response for each aspect can be seen in Table 5.

Table 5. Results of Student Response Test

Aspect	Weighted score	Average	Quality (%)	Criteria
Materials in Learning Media	47,93%	30,586	76,47%	Baik
Ease of Use	27,77%	17,724	73,85%	Baik
Appearance	24,30%	15,517	77,59%	Baik
Total	**100%**	**63,827**	**75,98%**	**Baik**

Based on the results of the trial, students on the virtual laboratory media as a whole obtained an average score of 63.827 so that the response was quite positive with good quality with a quality percentage of 75.98%. These results were obtained based on the literature of the calculation research conducted by Putri and Arianingrum (2024) by changing the average score into a qualitative value according to the ideal assessment criteria. Every aspect of the media developed received a fairly positive response from students. The learning material aspect obtained good quality with a quality percentage of 76.47%. The user-friendliness aspect obtained good quality with a quality percentage of 73.85%. The appearance aspect obtained good quality with a quality percentage of 77.59%.

Material aspects of learning media, with an overall average of 30.586. The results of the study showed that students were better able to follow learning well using virtual electrochemistry laboratory media. Based on student responses, 72.4% of students agreed, 24.1% strongly agreed, and 3.4% disagreed. Students also prefer interactive teaching and learning processes because they help them understand electrochemistry material faster. This is supported by student responses, where 68.9% agreed, 27.9% strongly agreed, and 3.4% disagreed. The material and illustrations provided through virtual lab media have been shown to help students remember electrochemistry material more easily. Based on student responses, 75.9% agreed, 10.3% strongly agreed, and 13.8% disagreed. In addition, the application of virtual laboratory learning media makes students more active in participating in electrochemistry learning. Student responses showed that 79.3% agreed, 17.2% strongly agreed, and 3.4% disagreed. The electrochemistry material presented in virtual lab media is considered complete. Based on student responses, 79.3% agreed, 3.4% strongly agreed, and 17.2% disagreed.

User-friendliness aspect, with an overall average of 17.724. The results of the study showed that learning using virtual laboratory media was considered more enjoyable than watching learning videos on YouTube. The response results showed that 68.9% of students agreed, 17.2% strongly agreed, and 13.8% disagreed. Students were also more enthusiastic about participating in chemistry learning with virtual electrochemistry lab practicums. Based on student responses, 75.9% agreed, 6.9% strongly agreed, and 17.9% disagreed. Virtual lab learning media was also considered more efficient in terms of quota because it can be used multiple times without requiring an internet connection. Student responses showed that 86.2% agreed, 10.3% strongly agreed, and 3.4% disagreed.

Appearance aspect, with an overall average of 15.517. The results showed that the virtual learning media of the electrochemistry lab was considered more varied and interesting. Based on student responses, 75.9% agreed, 24.1% strongly agreed, and 0% disagreed. The appearance of the virtual lab media also greatly attracted students' interest in learning electrochemistry material. Student responses showed 75.9% agreed, 24.7% strongly agreed, and 3.4% disagreed. The text presented in the virtual electrochemistry lab media was considered clear and easy to read. Based on the response results, 75.9% of students agreed, 24.7% strongly agreed, and 0% disagreed.

Based on the research results, the virtual electrochemistry laboratory learning media received positive responses from students in various aspects, such as material, ease of use, and

appearance. The majority of students stated that this media helped them understand the concept of electrochemistry better, increased learning motivation, and was more efficient in terms of quota because it could be used offline. The attractive appearance and clear text further strengthen its effectiveness as a learning aid.

One of the main factors that makes this virtual laboratory effective is the integration between material and practicum in one interactive media. Students not only get theory, but can also carry out experimental simulations independently. This is in accordance with research by Harahap & Sinegar (2020) which states that virtual laboratory-based media can create more enjoyable and less monotonous learning. In addition, the use of 2D animation in this media supports conceptual understanding, as found in research by Apriansyah et al (2020), which shows that animation is more effective in conveying material because it involves the senses of sight and hearing.

Positive responses can also be seen from students' enthusiasm in using this media repeatedly. They feel freer to repeat the simulation until they really understand the material, unlike direct practicums which have limited time and tools. This is reinforced by research by Ikhsan et al (2020), which states that virtual laboratories allow students to repeat experiments as many times as needed to strengthen their understanding. In addition, research by Hikmah et al (2017) also found that virtual laboratories can improve students' focus and mastery of concepts because they are packaged in an attractive format.

Overall, the validation results and student responses in this study are in line with previous studies that confirm the effectiveness of virtual laboratories in improving understanding of chemical concepts. However, there are several challenges that need to be considered in further development. One of the main obstacles is the limited device compatibility. Currently, the media can only be used on Windows-based computers or laptops and Android smartphones, so students who use iOS devices cannot access it. Therefore, further development is needed so that this media is compatible with various operating systems. In addition, in order for this virtual laboratory to be accessible to more users, publication on platforms such as the Play Store needs to be considered. With wider distribution and increased cross-device compatibility, this 2-dimensional virtual laboratory-based interactive media can be an innovative solution in supporting electrochemistry learning and practicum in various educational environments.

CONCLUSION

Based on the results of research and development of interactive learning media based on 2-dimensional laboratories conducted by researchers, it can be concluded that Interactive learning media based on 2-dimensional virtual laboratories on electrochemistry material has been validated by 3 validators and analyzed using Aiken's V content validity with a high validity result of 0.86 so that the virtual laboratory media developed by researchers is suitable for use.

Student responses to interactive learning media based on 2-dimensional virtual laboratories on electrochemistry material showed good results with an overall quality percentage of 75.98%. So that this learning media can be used continuously in the learning process, especially on electrochemistry material. This media has been proven to have a positive impact on electrochemistry learning, especially in:

a. Improving understanding of electrochemistry concepts through interactive visualization and experimental simulations that can be repeated at any time.
b. Developing students' practical skills by providing a more flexible laboratory experience than conventional practicums.

c. Increasing interest and motivation to learn because the presentation of material is more interesting, not monotonous, and easier to access without the need for an internet connection.
d. Overcoming the limitations of laboratory facilities by providing electrochemical experiment simulations that can be performed without relying on the equipment and chemicals in a real laboratory.

RECOMMENDATION

Based on the results of this study, the researcher proposes several recommendations as follows:

1. Further Research

   Further research is needed regarding the effectiveness of using this virtual laboratory in learning and practicing electrochemistry in various educational environments.

2. Development of Device Compatibility

   Currently, the media can only be used on Windows-based computers/laptops and Android smartphones. Therefore, further development is needed so that this media can be used on devices with the iOS operating system, so that more students can access it.

3. Wider Distribution

   To increase user reach, this media needs to be published on platforms such as the Play Store or Learning Management System (LMS) so that it can be downloaded and used more widely by students and teachers.

4. Trial on a wider scale

   To measure the effectiveness of the media more comprehensively, implementation on a larger scale is needed in various schools with diverse student backgrounds

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