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Android Based E-Module Development Integrated Virtual Laboratory in Learning Chemistry of Electrochemical Cell Materials

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Abstract

Chemistry education students experience misconceptions in studying electrochemical material, especially voltaic cells and electrolytic cells, because most of it is abstract. Most students understand electrochemical material only from the macroscopic aspect, so students' understanding of electrochemical cells is relatively low; therefore, it is necessary to use the right media to help overcome misconceptions when studying electrochemical material. This research aims to develop an Android-based e-module integrated with a virtual laboratory on electrochemical cell material produced as a chemistry learning medium. This research is research and development using the ADDIE model with stages, namely analysis, design, development, implementation, and evaluation. Validation of the Android-based e-module integrated with a virtual laboratory was carried out by two UNTAD chemistry education lecturers and implemented by trial on 20 chemistry education students in semesters 1 and 5. The conclusion of this research shows that the Android-based e-module integrated in the virtual laboratory is valid and feasible to use as a learning medium to overcome misconceptions experienced by chemistry education students when studying electrochemistry, as shown by the results of material validation and media validation, which were declared very valid with a value of 85.19% and 83.33%, and product trial results with a value of 81.86%, which is included in the very feasible category.

Keywords: E-module, virtual Laboratory, electrochemistry, chemistry learning

Introduction

Chemistry is a branch of natural science that studies the properties of matter and its structure. Apart from that, material changes are also studied, which are described through laws, principles, concepts, and theories (Indrayani, 2013). Chemistry integrates abstract and concrete concepts in learning related to three aspects, namely macroscopic, microscopic, and symbolic (Harianto et al., 2019).

Microscopic and symbolic aspects are the reasons why students find it difficult to study chemistry, one of which is the chemistry topic, namely electrochemistry (Suryati et al., 2022). Electrochemistry is a chemical subject related to chemical processes that cause electrons to move on electrodes. The movement of electrons from one element to another is called a reduction-oxidation (redox) reaction, which is characterized by the transfer of electrons between chemical species. In the reduction reaction, electrons are captured, while in the oxidation reaction, electrons are released in the electrochemical cell as the delivery medium (Harahap, 2016). The events of capturing and releasing electrons in redox reactions in electrochemical cells are part of the microscopic aspect because they cannot be seen with the naked eye or occur directly. This makes it difficult for students to understand redox and electrochemical material, and most teachers in high school only teach at the macroscopic and symbolic level, making it even more difficult for students to understand this material (Harianto et al., 2019).

Electrochemistry is a chemistry topic that is divided into two parts, namely electrolysis cells and voltaic cells. This research focuses on the topic of voltaic cells, namely the Daniell cell and electrolysis cells, which discuss fused NaCl. This is because these two topics are difficult for students to understand, which makes students misunderstand the concepts (Aisyah et al., 2020). According to the results of observations made by Rasmawan & Erlina (2021) in their research entitled developing an Android-based electrochemical e-book application to foster student self-directed learning, it was stated that the majority of chemistry education study program students had difficulty solving electrochemical concept questions, especially in explaining processes. the occurrence of electric current in galvanic cells and the reactions that occur in electrolysis cells. This is due to a lack of study of the processes or reactions that occur in galvanic cells and electrolytic cells during high school. The learning style factor, which is only determined by the teacher, is also the cause of students' low ability to understand electrochemical material because of students' low ability to seek their own understanding through independent study. Apart

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from that, in previous research, it was said that most students understood electrochemical material only from the macroscopic aspect (Supriadi et al., 2018).

Based on the results of previous observations and research, one of the efforts to overcome the misconceptions experienced by students in studying electrochemical material, especially electrolysis cells and voltaic cells, is to use appropriate learning media according to chemistry topics so that it becomes an alternative for students in understanding the material (Aisyah et al., 2020). Multimedia applications can help the information search process, show real simulations, and provide literacy for students in learning activities, so that they will increase student learning activities and completeness (Nursuhud et al., 2019). Therefore, researchers developed an android-based e-module application integrated with a virtual laboratory as an effort to overcome misconceptions and as a medium for communicating material about electrolysis cells and voltaic cells, especially Daniell cells. The e-module developed is a virtual laboratory-integrated Android application created using Adobe Animate and Adobe AIR SDK 5.0 software. This e-module can be useful for students in making learning more effective both inside and outside the classroom, overcoming misconceptions about chemistry learning through the virtual laboratory contained in the e-module, and increasing student learning motivation.

Methods

The type of research carried out is research and development. The subjects of this research included 2 FKIP UNTAD chemistry education lecturers and 20 UNTAD chemistry education students in semesters 1 and 5 from a total population of 65 people.

The development model used is the ADDIE model. The ADDIE model consists of 5 stages, namely analysis, design, development, implementation, and evaluation (Winaryati, 2021).

Stage 1 (analysis)

The analysis stage of this development research includes several stages, including:

a. Analyzing course learning outcomes and expected final abilities in electrochemical cell material through literature studies of the curriculum so that the indicators to be achieved from the learning outcomes of the courses studied can be identified.
b. Analyzing gaps that occur in the learning process through observations in literature reviews in the form of relevant research journals.
c. Analyzing product needs with the aim of obtaining information regarding all needs, such as module and application material needs, user needs, and application development needs, as well as formulating product designs and working diagrams.

Stage 2 (design)

The design stages in this development research include several stages, including:

a. Designing a series of program command flows on the developed virtual laboratory-integrated Android-based e-module, which is described in the form of a flowchart.
b. Collecting all the requirements needed to develop an Android-based electronic module integrated with a virtual laboratory, such as images for designing e-module covers and application icons, e-module material sources, application marker images, and evaluation tests in the form of multiple-choice questions along with answer keys.
c. Creation of application work diagrams and product appearance sketches that refer to the product design formulation resulting from the product requirements analysis stage.
d. Determine the length of production time so that the implementation of interactive module design and development activities can proceed according to plan.

Stage 3 (Development)

The development stage that needs to be carried out is realizing the media design that was prepared in the previous stage into an e-module that is integrated into a virtual laboratory. Then the instrument is created, and the module is validated by expert judgment. This aims to determine the suitability of the media that has been developed.

Stage 4 (Implementation)

The implementation stage of this development research includes validation of the expert judgment module and trials on students in large groups. This aims to determine the response of users to the e-module that has been developed.

Stage 5 (Evaluation)

The evaluation stage is the stage of reflecting and making improvements to things that need to be improved at the implementation stage by means of identification and refinement. If there is no improvement in the media developed, then the media is suitable for use as a chemistry learning medium.

The instruments used were a material expert validation questionnaire, a media expert validation questionnaire, and a user assessment questionnaire. The three questionnaires were prepared using a rating scale in the form of quantitative questions, and scoring was carried out using a Likert scale. The validation sheet was shown to the chemistry education lecturer at FKIP UNTAD, while the user assessment sheet was shown to the students.

Results and Discussion

1. Analysis stage

This stage is the stage of analyzing development needs by formulating problems that occur in the field and collecting data before designing the e-module. The analysis phase procedure in this development research includes several stages, including:

a. Analyzing course learning outcomes and expected final abilities in electrochemical cell material is carried out by studying literature on the curriculum.
b. Analyzing gaps that occur in the learning process through observations in literature reviews in the form of relevant research journals. This stage aims to obtain information regarding gaps that occur in the learning process carried out by students in electrochemical cell material. The observation results show that there are gaps in the learning process, namely:
   1) Most students understand electrochemical material only from the macroscopic aspect.
   2) Students' low understanding of electrochemical cells
   3) There are misconceptions experienced by students in studying electrochemical cell material, especially electrolysis cells and voltaic cells, because it is abstract.
c. Analyzing product needs with the aim of obtaining information regarding all needs, such as module and application material needs, user needs, and application development needs, as well as formulating product designs and working diagrams. In chemistry education, students' understanding of electrochemical material is still low because there are misconceptions experienced by students in studying electrochemical cell material, especially electrolysis cells and voltaic cells, which are abstract in nature, so students need learning media to help them understand electrochemical cell material, one of which is e-module (Aisyah et al., 2020).

2. Design stage

The design stage is the stage of creating the e-module design and virtual laboratory application. The design stage of an Android-based e-module integrated with a virtual laboratory on electrochemical material is carried out in several stages, namely:

a. Design Stage Flowchart: Making a flowchart is done using symbols that describe program components and arrows that describe the sequence of the program to be created. The design of this virtual laboratory-integrated Android-based e-module was carried out in several stages so that it ran well, as shown in Figure 1.

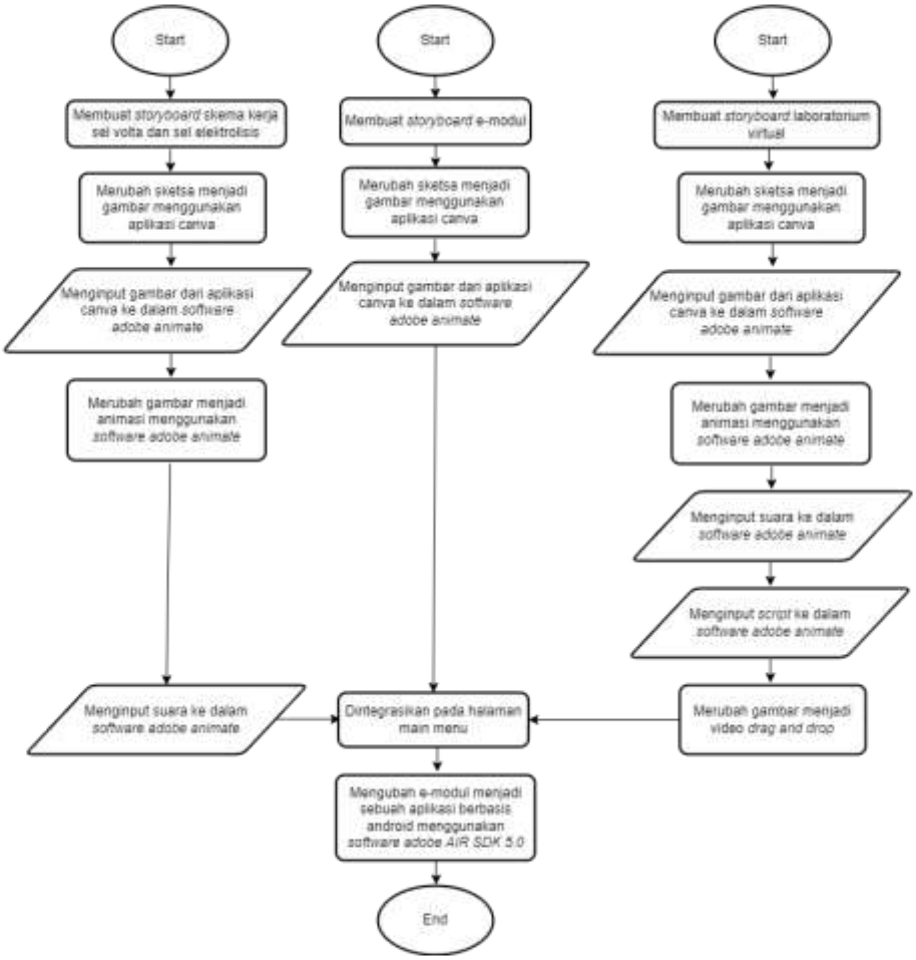

Figure 1. E-Module flowchart and virtual laboratory flowchart

b. Gathering product requirements needed in the development of Android-based e-modules integrated with virtual laboratories on electrochemical material, such as images for designing e-module covers and application icons, e-module material sources, e-module application marker images, and evaluation tests in the form of multiple-choice questions with an answer key.

c. Creating product appearance sketches and application work diagrams based on product design formulations resulting from the product requirements analysis stage. Making a sketch of the product appearance using the Canva and Adobe Animate applications to design the e-module background, e-module application marker images, application icon, and e-module cover as in Figure 2.

Figure 2. Example of E-module design based on android integrated virtual laboratory on electrochemical materials

d. Determine the manufacturing time. This activity aims to ensure that the implementation of design and development activities for an Android-based e-module integrated with a virtual laboratory can proceed according to plan.

3. Development stage (Development)

The development stage of this research was carried out in several stages, namely

a. Realizing the media design that was prepared in the previous stage into an Android-based e-module integrated into a virtual laboratory on electrochemical materials. The results of the design for creating learning e-modules are as follows:

Figure 3. Front cover view

Figure 4. Main menu display

Figure 3. Display of course learning outcomes

Figure 6. Material display

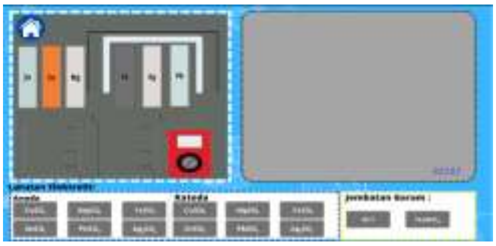

Figure 7. Virtual laboratory view

b. Product validation/feasibility test

After the e-module development process, it is then validated by material expert validators and media experts with the aim that researchers can find out the weaknesses and shortcomings of the product being developed. The results of e-module validation by material experts and media experts are as follows:

1) Material validation

Material validation was carried out by selected material experts to assess the quality of the material and the benefits of the integrated Android-based e-module in the virtual laboratory as a learning medium for electrochemical cell material.

Validation results by material experts are calculated using the descriptive analysis method by calculating the percentage level of validation results using the percentage formula.

Table 1. Validation results of the validity of e-module material

No	Aspect	Indicator Score	Criteria
1.	Language	80%	Very valid
2.	Material Contents	90.48%	Very valid
3.	Media Effects on Learning Strategies	80%	Very valid

Based on the results of assessment calculations by material experts, it was concluded that the average value was 83.33%, which was included in the very valid category. Looking at the validation results by material experts in Table 1, the indicator that received the highest score was the assessment of the validity of the content aspect of the material, with a percentage score of 90.48% in the very valid category. The indicators that received the lowest scores were the assessment of the validity of linguistic aspects and the assessment of the validity of aspects of media effects on learning strategies, with respective percentage scores of 80%, but they were in the very valid category.

The results of the material validation assessment by material experts for each assessment indicator are in the very valid category. However, there are several suggestions from material expert validators, namely making the e-module design better and more attractive, adding attractive colored images to the e-module to make it more interactive, and providing procedures for using the e-module.

2) Media validation

Media validation is carried out by selected media experts to assess the level of validity from the media side, which is seen in several aspects of media validity assessment, namely system quality aspects, software engineering aspects, language aspects, and visual appearance aspects.

Validation results by media experts are calculated using the descriptive analysis method by calculating the percentage level of validation results using the percentage formula.

Table 2. Results of validation of media validity aspects in the E-module

No	Aspect	Indicator Score	Criteria
1.	Language	100%	Very valid
2.	Software Engineering	76.19%	Valid
3.	Visual Display	80.95%	Very valid
4.	Sistem Quality	77.78%	Valid

Based on the results of assessment calculations by media experts, it was concluded that the average value was 83.33%, which was included in the very valid category. Looking at the validation results by media experts in Table 2, the indicator that received the highest score was the assessment of the validity of linguistic aspects, with a percentage score of 100% in the very valid category. The indicator that received the lowest score was the assessment of the validity of the software engineering aspect, with a percentage score of 76.19%, but it was in the valid category.

The results of media validation assessments by media experts are, on average, in the very valid category. However, there are several suggestions from material expert validators, namely in the initial display to make the words "Electrochemistry" more prominent or increase the font size, illustrative images to understand the definition of redox are less clear (blurry) as well as redox balancing reaction equations, before the table to give an introduction or name table, the size of the text box is adjusted to the text content, it is best to add a menu for sub-material (due to the large number of sub-materials) to make it easier to navigate when entering a particular sub-material, it is best to insert animations in this e-module like in other e-modules (for example flip) because the voice in the voltaic cell scheme is too long and the image is static, we should add instructions/hints for using the e-module so that the principle of independence is lacking, and we should add a close button to the score page for the results of the practice questions.

3) Virtual laboratory validation

Virtual laboratory validation is carried out by media experts and selected material experts to assess the level of validity of the virtual laboratory.

Virtual laboratory validation results are calculated using the descriptive analysis method by calculating the percentage level of validation results using the percentage formula.

Table 3. Validation Results of Virtual Laboratory Validity Aspects

No	Aspect	Indicator Score	Criteria
1.	Material Contents	100%	Very valid
2.	Media Effects on Learning Strategies	100%	Very valid
3.	Software engineering	88.89%	Very valid

Based on the results of assessment calculations by media experts and material experts, it was concluded that the average value was 91.67%, which was included in the very valid category. Looking at the validation results in Table 3, the indicator that got the highest score was the assessment of the validity of aspects of material content and media effects on learning strategies, with each getting a percentage score of 100% in the very valid category. The indicator that received the lowest score was the assessment of the feasibility of the software engineering aspect, which received a percentage score of 88.89% and was in the very valid category.

The results of media validation assessments by media experts and material experts are, on average, in the very valid category. However, there are several suggestions from material expert validators and media experts, namely to add instructions or hints for using the virtual laboratory so that the principle of independence is not lacking.

4. Implementation stage

At this stage, the Android-based e-module integrated with the virtual laboratory, which has been developed and revised in accordance with criticism and suggestions from material experts and media experts, is implemented in the classroom. This trial was carried out at the Chemistry Education Study Program, Tadulako University, Palu.

This trial was carried out to determine the feasibility of an Android-based e-module integrated with a virtual laboratory based on the responses and assessment results of students as application users. This trial was carried out on 20 chemistry education students in semester 1 and semester 5.

Product trial results are calculated using the descriptive analysis method by calculating the percentage level of product trial results using the percentage formula. Based on this formula, the data on student response assessment results can be seen in Table 4.

Table 4. Student response assessment results as users

No	Aspect	Indicator Score	Criteria
1.	Clarity of Messages and Information	81.89%	Very worthy
2.	Clarity of Procedures in E-Modules	80.42%	Very worthy
3.	E-Module Eligibility	83.13%	Very worthy
4.	Influence and Relationship of E-Modules on Students	81.15%	Very worthy
5.	General E-Module View	82.34%	Very worthy

Based on the results of calculating student response assessments, it was concluded that the average score was 81.86%, which was included in the very appropriate category. Looking at the results of assessing student responses as application users in Table 4, the indicator that received the highest score was the media feasibility assessment in the e-module feasibility aspect, with a percentage score of 83.13% in the very feasible category. The indicator that received the lowest score was the assessment of media suitability in the aspect of clarity of procedures in the e-module, with a percentage score of 80.42%, but it was in the feasible category.

The results of the assessment of student responses as application users are, on average, in the very feasible category. However, there are several suggestions from students as application users, namely clarifying the procedures for using e-modules and virtual laboratories and adding a material download feature to the e-module so that it can be downloaded by users.

5. Evaluation stage

The evaluation stage is the final stage of the ADDIE model. At this stage, it is a stage to see whether the product being developed, namely an Android-based e-module integrated with a virtual laboratory on electrochemical cell material, can be said to be suitable or not as a chemistry learning medium.

The evaluation stage can be seen based on the results of measuring student responses to questionnaires as application users using a Likert scale. The questionnaire contains 67 positive statements for students as application users. Based on the research results, it shows that the Android-based e-module integrated with a virtual laboratory on electrochemical cell material is very suitable for use in chemistry learning; however, the media developed still needs to be improved and developed in accordance with criticism and suggestions from students as application users so that it can be used as a medium. learning in class and independently and can help students overcome misconceptions when studying electrochemical cell material.

This development research aims to determine the feasibility of developing an Android-based e-module integrated with a virtual laboratory on electrochemical cell material as a chemistry learning medium. An e-module is a module in electronic format that is run on a computer and can display text, images, and video animations. The advantage of e-modules is that they reduce the use of paper in the learning process and can help students measure and control their learning intensity (Laili et al., 2019). With the development of e-learning modules, it is hoped that it can help students with independent learning.

This development research uses the ADDIE model as a supporting procedure for conducting research. The ADDIE development model consists of five stages, namely analysis, design, development, implementation, and evaluation (Winaryati, 2021). The ADDIE model is widely used by researchers in developing learning media products that are right on target, effective, and efficient because this model has advantages in its work stages, namely systematic (Adesfiana et al., 2022). This is in accordance with research conducted by Panggabean & Purba (2021), which used the ADDIE approach. The research results show that the e-module developed is classified as valid or suitable for application in learning and can improve students' chemical problem-solving abilities on thermochemical material. Research conducted by Ninawati et al. (2021), who also used ADDIE development, shows that the e-module developed is suitable for use as independent teaching material.

Development of an integrated virtual laboratory e-module used for practicum activities in the e-module. The virtual laboratory developed is made to resemble the real situation so that it can be used as an alternative for carrying out practical learning about electrochemical cells without having to go to the laboratory. Learning with the help of virtual laboratories can foster students' interest in knowing new things, increase students' understanding of the material being taught, and anticipate the unpreparedness of tools and materials used for practicums in real laboratories. This is in accordance with the opinion of Hikmah et al. (2017) and Ramadhani et al. (2021) that a virtual laboratory is an interactive science simulation in the form of a science experiment simulation with the help of applications on a computer that are used to help the learning process improve students' understanding of the material being taught and anticipate the unpreparedness of real laboratories. Apart from that, virtual laboratories aim to increase students' interest in learning new things.

The developed virtual laboratory integrated Android-based e-module contains six main menus consisting of an electrochemical cell material menu, a voltaic cell work scheme menu, an electrolysis cell work scheme menu, a virtual laboratory menu, a practice questions menu, and a material summary menu. This e-module is equipped with a color display, pictures supporting the material, and a voiceover explaining the working scheme of a voltaic cell and the working scheme of an electrolysis cell. The e-module display and supporting images were designed using the Canva application and Adobe Animate software. Then the material in the e-module was prepared using Microsoft Word 2010 software and designed with the help of the Canva application. This research also used Adobe AIR SDK 5.0 software. to convert e-modules into Android-based applications. The material in the e-module contains material about oxidation-reduction reactions, voltaic cells, and electrolysis cells, which is equipped with 10 multiple-choice practice questions regarding electrochemical cells. Then the virtual laboratory in the e-module can be used for practical work on determining cell potential in voltaic cells, which is equipped with laboratory tools and materials for designing voltaic cells as well as buttons to select the solution on the salt bridge, the solution on the cathode, and the solution on the anode. The Android-based e-module on electrochemical cell material can be accessed via the page https://bitly.ws/35RyN, while the virtual laboratory integrated with the e-module can be accessed via the page https://bitly.ws/35RzV.

Based on validation results from material experts and Chemistry Education lecturers at Tadulako University, the average score for all aspects is 83.33%, which is included in the "very valid" category. The aspects assessed are linguistic aspects, material content aspects, and media effect aspects on learning strategies. The assessment indicators for aspects assessed by material experts are based on the clarity of the material presentation and ease of access by users to the Android-based e-module integrated with the virtual laboratory. In the linguistic aspect, a percentage score of 80% was obtained with the criteria "very valid," meaning that the language used in the e-module can help students understand the intent and meaning of the material being studied (Panjaitan et al., 2021). Then, in the aspect of media effects on learning strategies, a percentage value of 80% was obtained. This shows that the learning media developed has an effect on learning strategies, such as being able to minimize misconceptions experienced by students when studying electrochemical material, which can encourage independent learning and student curiosity when studying electrochemical material, so that the media developed is suitable for use in helping students master the right concept (Giyanto et al., 2020). This is in accordance with research conducted by Panggabean and Purba (2021) that the development of innovative teaching materials such as e-modules, which can be accessed and downloaded online as teaching materials or independent learning resources for students, can help improve understanding, mastery, and problem-solving abilities. chemistry students. Then the highest percentage score was obtained in the content aspect of the material, namely 90.48%, with the criteria "very valid," meaning that the suitability of the learning outcomes to be achieved with the material presented in the form of material descriptions, pictures, videos, and questions gives an idea of what is expected from teaching materials and can be delivered to obtain complete knowledge according to what is expected (Lau et al., 2019). Apart from that, the concepts are presented sequentially, starting with the prerequisite concepts, which are used to study the next concept in more depth (Rasmawan & Erlina, 2021). According to San et al. (2020), a good teaching material is if the concepts studied are ordered from basic concepts or prerequisite concepts, making it easier for students to learn broader concepts, activate the knowledge or basic concepts they already have, and help develop skills in linking relationships between concepts.

The validation results from media experts by Chemistry Education Lecturers at Tadulako University obtained an average score for all aspects of 83.33% in the "very valid" category. The aspects assessed include system quality aspects, software engineering aspects, linguistic aspects, and visual appearance aspects. Assessment indicators for the aspects assessed include ease of access for e-module users and virtual laboratories, clarity and suitability of the e-module's visual appearance, suitability of the language used in the e-module, as well as suitability of the e-module being developed with the characteristics of the e-module, namely self-instructional, adaptive, and user-friendly. This is in accordance with Daryanto's (2013) opinion that a good learning e-module fulfills characteristics including self-instruction, self-contained, stand-alone, adaptive, flexible, and user-friendly.

In the system quality aspect, a percentage value of 77.78% was obtained, meaning that the Android-based e-module system integrated with virtual laboratories is easy to use, can be accessed without any problems, and provides several features and functions that users need to study the material independently and help students who experience problems. learning difficulties (Laili et al., 2019). According to the Directorate of High School Development (Asmiyunda et al., 2018), e-modules must contain components such as being delivered via computer-based electronic media, utilizing various electronic media functions, utilizing various software application options, and being designed by taking into account learning and learning principles.

The software engineering aspect obtained a percentage value of 76.19%, meaning that in the development of the Android-based e-module integrated with the virtual laboratory, there were no errors and script commands from the Android system could run, so it can be concluded that the e-module developed functions well and is suitable for use (Nazar et al., 2020). The visual display aspect obtained a percentage score of 80.95%, meaning that the descriptions of material, images, videos, and questions and discussions displayed in the e-module developed were very interesting and clear, and the content of the material presented was easy to understand, so that students were interested in using the e-module. According to Zulherman et al. (2021), the attractiveness of the e-module application can motivate potential users to use it in studying electrochemical concepts, and the clarity of the presentation displayed on the e-module is appropriate to the potential user's level of understanding so that it can be used to help potential users learn the concepts presented. In the linguistic aspect, the highest percentage score was 100%, meaning that the language used in the e-module is easy to understand so that it can help students understand the intent and meaning of the material being studied (Panjaitan et al., 2021).

Based on the results of virtual laboratory validation from material experts and media experts by two Chemistry Education lecturers at Tadulako University, the average score for all aspects is 91.67%, which is included in the "very valid" category. The aspects assessed are aspects of material content, aspects of media effects on learning strategies, and aspects of software engineering. The assessment indicators for aspects assessed by material experts and media experts are adjusted to the use of virtual laboratory simulations and the characteristics of virtual laboratories. According to Padman & Memon (2020), the designed virtual laboratory must meet the following characteristics: reconfigurable, heterogeneous, scalable, cost-effective, robust, maintainable, realistic, and insulated. In the content aspect of the material, a percentage score of 100% was obtained with the criteria "very valid," meaning that the virtual laboratory is well integrated into the Android-based e-module so that it can make it easier for students to study electrochemical material. Then, in the aspect of media effects on learning strategies, a percentage value of 100% was obtained. This shows that the virtual laboratory developed and integrated into an Android-based e-module has an effect on learning strategies such as being able to minimize misconceptions, encouraging independent learning, and fostering student curiosity when studying electrochemical material, so that the media developed is suitable for use in helping students master the concepts. right (Giyanto et al., 2020). This is in accordance with research conducted by Gunawan et al. (2015) that learning using a virtual laboratory can improve students' mastery of concepts, especially in studying electrochemical material at the macroscopic, submicroscopic, and symbolic levels, thereby minimizing the misconceptions experienced by students when studying electrochemical material. According to Jagodzinski & Wolski (2014), learning in virtual laboratories has a positive impact on increasing teaching efficiency, increasing students' ability to remember information, and showing greater resilience in remembering material information (concepts). Based on this, according to Muti'ah et al. (2017), virtual laboratories as a modified chemical demonstration medium can increase students' understanding regarding the topics of reactions at electrodes, the mechanism of electric flow in electrolyte solutions and salt bridges, the flow of electric charges in external circuits, as well as closed and open circuits. The modified chemical demonstration medium in the form of a virtual laboratory can present electrodes in a macroscopic or real way; therefore, students can observe and try directly so that their interaction with the object being studied is stronger in constructing the concept.

In the software engineering aspect, a score of 88.89% was obtained with the criteria "very valid," meaning that the virtual laboratory developed and integrated into the e-module did not experience errors and every command in the script from the Android system could run, so it could be said to be a virtual laboratory that can run and function well (Nazar et al., 2020).

It can be concluded that the assessment given by material experts and media experts on the virtual laboratory integrated Android-based e-module is very valid and worthy of being tested on chemistry education students in advanced basic chemistry courses with revisions according to suggestions given by material experts and media experts. The comments or suggestions from material experts for the Android-based e-module integrated with virtual laboratories include adding colored images to make the e-module more interactive, adding practice questions related to the existing material, adding instructions for using the e-module, and beautifying the design to make it more attractive. Meanwhile, comments or suggestions from media experts include adding instructions for using e-modules and virtual laboratories, adding a "close" button on the results page for working on practice questions, improving the size of the text box so that it more closely matches the content of the text, improving the display so that it is more clearly read, and adding a menu for sub-materials on the material page to make it easier to select sub-materials.

After revisions were made according to criticism and suggestions by material experts and media experts and declared valid by the two experts, it was then continued with product trials carried out by 20 students of chemistry education in semester 1 and semester 5 and as many as 20 students through student response questionnaires as application users. (user), which contains 67 statements covering aspects of clarity of messages and information, aspects of clarity of procedures in e-modules, aspects of feasibility of e-modules, aspects of the influence and relevance of e-modules on students, and aspects of e-module appearance in general.

The assessment results obtained an average score of 81.86% in the "very feasible" category. Based on this data, it can be interpreted that students assess the developed virtual laboratory-integrated Android-based e-module as suitable for use in the learning process in class and in independent learning and that it can help students overcome misconceptions when studying electrochemical cell material. The developed virtual laboratory-integrated Android-based e-module still requires several additional revisions, such as clarifying the procedures for using the e-module and virtual laboratory and adding a material download feature to the e-module so that it can be downloaded by users.

The e-module that was developed has several advantages, including the presentation of material in the e-module, which includes material on reduction-oxidation reactions and electrochemical cells in full. There are practice questions that can help students measure their understanding of the material that has been studied in the e-module, and there are activities. The virtual laboratory simulation practicum is equipped with instructions for its use so that it can help students carry out virtual practicums and increase understanding of the material being taught. The language used is simple and easy to understand, and it can be used for independent learning because the e-module is equipped with instructions for using e-modules and instructions for using the virtual laboratory. Another advantage is that the e-module can be accessed anywhere and at any time without being limited by space and time. This e-module has the advantage of being able to be accessed without being connected to an internet network; it can be installed on Android or on a laptop, and the application storage size does not take up much space, so users can easily install and use e-modules without limited space and time.

Conclusions

Research into the development of an Android-based e-module integrated with a virtual laboratory on electrochemical cell material as a whole is suitable for use as a learning medium in accordance with the results of the assessment of material experts and media experts. However, this cannot be separated from the researcher's limitations during carrying out this research, including when media validation was carried out by media experts and material experts. It was found that the writing of the reaction equations in the e-module was unclear, and there were no instructions for using the e-module or instructions for using the virtual laboratory, resulting in errors. This needs to be improved in order to perfect the e-module being developed

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