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Augmented reality-based flashcard media to improve students' concept understanding in chemistry learning

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ABSTRACT

The reaction processes in voltaic cells are abstract, so media is needed to visualize them. This research aims to develop flashcard media based on augmented reality using voltaic cell material. This research uses the ADDIE model, including analysis, design, development, implementation, and evaluation. The research instruments used were product quality assessment sheets and student response sheets. Based on the results of assessments from material experts, media experts, reviewers, and student responses, ideal percentages were obtained at 90%, 89.23%, 90.58%, and 98.3%. Based on the assessment results, it can be concluded that augmented reality-based flashcard learning media is included in the very feasible category. It can be used as an alternative media to increase students' understanding of concepts in voltaic cell material. This research emphasizes developing learning media by utilizing technological advances.

Media *flashcard* berbasis *augmented reality* untuk meningkatkan pemahaman konsep siswa dalam pembelajaran kimia

Keywords:

Augmented reality
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ABSTRACT

Proses reaksi yang terjadi pada sel volta bersifat abstrak sehingga diperlukan media untuk memvisualisasikannya. Tujuan penelitian ini untuk mengembangkan media *flashcard* berbasis *augmented reality* pada materi sel volta. Penelitian ini menggunakan model ADDIE meliputi *analysis, design, develop, implement*, dan *evaluate*. Instrumen penelitian yang digunakan berupa lembar penilaian kualitas produk dan lembar respon siswa. Berdasarkan hasil penilaian dari ahli materi, ahli media, reviewer, dan respon siswa diperoleh persentase keidealan sebesar 90%, 89,23%, 90,58%, dan 98,3%. Berdasarkan hasil penilaian dapat disimpulkan bahwa media pembelajaran *flashcard* berbasis *augmented reality* termasuk dalam kategori sangat layak dan dapat digunakan sebagai media alternatif untuk meningkatkan pemahaman konsep siswa pada materi sel volta. Penelitian ini memberikan implikasi pada pengembangan media pembelajaran dengan memanfaatkan kemajuan teknologi.

1. INTRODUCTION

Educational technology allows the learning process without limitations in space and time [1]. Educational technology is used to solve problems in education [2]. Educational technology can change the classroom learning mode from conventional to completely digital [3]. Educational technology facilitates learning by utilizing appropriate technology to create effective and efficient learning [4]. Educational technology can simplify the learning process and save energy and costs in the long term [5]. Educational technology can also make it easier for teachers to achieve learning goals [6]. Based on Law Number 14 of 2005, teachers must master educational technology to improve their professional competence so that the quality of learning produced is optimal [7]. However, facts in the field show that very few teachers still master and implement educational technology in learning [8]. The competency test results on 275,768 teachers in Indonesia showed that the average teacher mastery score on educational technology was only 41.5 out of a weighted score of 100 [9]. This data shows that educational technology is still not mastered by teachers.

Teacher competency measures a teacher's professionalism [10]. Teacher competency includes a set of knowledge, skills, and behaviours that teachers must possess and master in carrying out their duties [11]. Teacher competency is essential in determining classroom learning management quality [12]. Teachers must be able to use educational technology so that the learning process can take place more effectively [13]. Educational technology can stimulate students' minds and attention to optimize learning [14]. Therefore, teacher competence is needed in managing and utilizing educational technology to create engaging, effective, and efficient learning activities [15].

Teachers' skills in mastering educational technology are related to digital literacy abilities. Digital literacy is fundamental in using and creating digital-based media [16]. Digital literacy can make the delivery of material by teachers more effective to improve the quality of learning [17]. According to the results of research conducted by Asari [18], the digital literacy skills of teachers in the school environment still need to improve. Teachers' digital literacy skills can be enhanced through training and mentoring to utilize multimedia as teaching materials [19]. This activity can make it easier for teachers to create learning media and increase teacher professionalism [20]. Teacher professionalism in digital literacy is essential in improving students' cognitive, affective, and psychomotor knowledge [21]. However, the success of a lesson relies not only on the teacher's digital literacy competency in selecting and using media but also on students' ability to understand the concept of the material well [22]. Understanding concepts is related to students' ability to interpret material according to their intellectual ability [23]. Understanding concepts is not only formed through knowledge transfer but also independently by students [24]. Conceptual understanding is related to a set of ideas, procedures, and principles that are understood holistically and associated with each other [25]. Understanding concepts is essential for students to solve problems theoretically and in their application in everyday life [26]. Understanding concepts helps one understand the material being studied and follow learning at a higher level [27]. Lack of understanding of concepts can cause students to pay less attention and lose interest in learning [28]. Knowledge of concepts can be measured by asking and testing students' questions [29]. Students who understand the concept correctly will find it easier to understand the concept of the following material [30]. One way to increase students' understanding of concepts can be through using learning media in the learning process [31]. This research will use learning media to improve understanding of concepts.

Media Visual learning is a learning medium that can make it easier for students to understand material concepts [32]. One visual learning medium that can be used is flashcards [33]. Flashcards are picture cards equipped with words arranged effectively and efficiently. The images in flashcards can attract students' interest and attention in learning [34]. Most students are visual learners, so flashcards can make learning easier [35].

Flashcards generally measure 8 × 12 cm and can be adjusted to suit the student's comfort [36]. Flashcard media has many advantages, including being practical, easy to remember, fun, clarifying the material, and concrete [37], [38]. However, flashcard media has the weakness of only being able to display objects in two dimensions, so it requires integration with other technologies to visualize objects in three dimensions [39].

A discovery in the field of educational technology that can create three-dimensional objects is Augmented Reality (AR) [40]. AR can help make learning material easier for students to understand [41]. AR is an interactive media that can display objects from the virtual world to the real world in real-time through 3D animation [42]. AR helps build user perceptions and interactions in the real world [43]. Apart from that, AR can also provide images or information that is easier for students to understand [44]. The AR application is designed as a supporting media for flashcards to display visualizations of chemical material through markers on flashcards [45]. The research results show that AR can improve students' concept understanding [46]. AR can help illustrate abstract chemical material more concretely [47]. The voltaic cell is one of the abstract chemical materials that can be presented through AR.

A voltaic cell is a series of two electrodes with potential differences in an electrolyte solution [48]. These two electrodes can cause an electric current to flow in a circuit [49]. Voltaic cell material is complex because it requires integrating macroscopic, submicroscopic, and symbolic levels of representation [50]. Submicroscopic and symbolic aspects become obstacles for students in understanding voltaic cells because they cannot be seen directly [51]. Students experience difficulties, especially in determining the flow of electrons, choosing the anode and cathode, the processes that occur in the voltaic cell, and the function of the salt bridge [52]. These difficulties hinder students from understanding the reactions in voltaic cells [53].

Research on the development of AR-based media has been widely conducted, including the development of AR-based flashcards [38], the development of AR through flash card methods [39], the development of biology learning media with AR [40], the development of technology and the utilization of AR [41], the development of chemical molecule learning media with AR [44], and the development of multiple representation-based e-modules with AR [47]. However, no research has developed AR-based flashcard media for voltaic cell material.

Based on these problems, this research aims to develop flashcard learning media based on AR on voltaic cell material. This research is different from existing research, which does not use flashcard media as markers to display AR on voltaic cell material. This research has the novelty of using flashcard media, which helps increase students' interest and understanding [54]. This research is expected to increase students' conceptual understanding of voltaic cells. Additionally, AR makes teaching voltaic cell material easier based on educational technology.

Contribution to the literature

This research contributes to:

- Providing innovation in science education by introducing the use of AR technology
- Providing literature related to interactive learning media, thus facilitating educators in explaining the material being studied.
- Supporting a contextual learning approach through direct practice and theory.

2. METHOD

This research was a type of research and development (R&D). The research model adopted was the ADDIE model by Dick and Carry, which consists of 5 stages: analysis, design, development, implementation, and evaluation [55]. The analysis stage analyzed the need for learning media in teaching chemistry on voltaic cell materials to several high school chemistry teachers. After carrying out the analysis, the design stage was then carried out. At the design stage, researchers designed learning media according to students' needs and created an innovative learning media that could help students learn voltaic cell material. After completing the learning media design, the researcher developed the media according to the design. The media developed was then implemented in chemistry learning to find out directly to what extent the media helped students. The final stage was the evaluation stage to determine the advantages and disadvantages of learning media based on assessments and feedback from students, reviewers, media experts, and material experts. The ADDIE research model is illustrated in Figure 1.

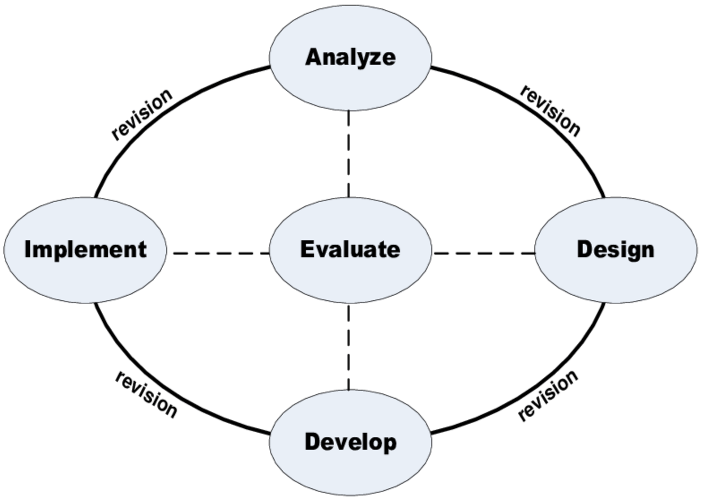


Figure 1. Stages in the ADDIE Model

The instruments used to collect data were product quality assessment sheets and student response sheets. The product quality assessment sheet determined the quality of the AR-based flashcard learning media being developed. Meanwhile, the students' responses aimed to discover the application of AR-based flashcard media in helping students understand the basic concepts of voltaic cell material. The selection of students as respondents was carried out randomly because the data collection method was the simple random sampling method. The validation results of material experts, media experts, and reviewers were analyzed using a Likert scale.

Furthermore, students' response sheets were given to the twelfth-grade high school students for product trials. The percentage of student response test results was calculated by adding the student scores, dividing them by the number of students, and multiplying the results by 100%. The results of these calculations were analyzed using the Guttman scale.

3. RESULTS AND DISCUSSION

After carrying out various stages in research into the development of AR-based flashcard media on voltaic cell material, the results obtained in this research were the results of assessments by material experts, media experts, reviewers, and student responses. The following is an explanation of the results of each stage in this research.

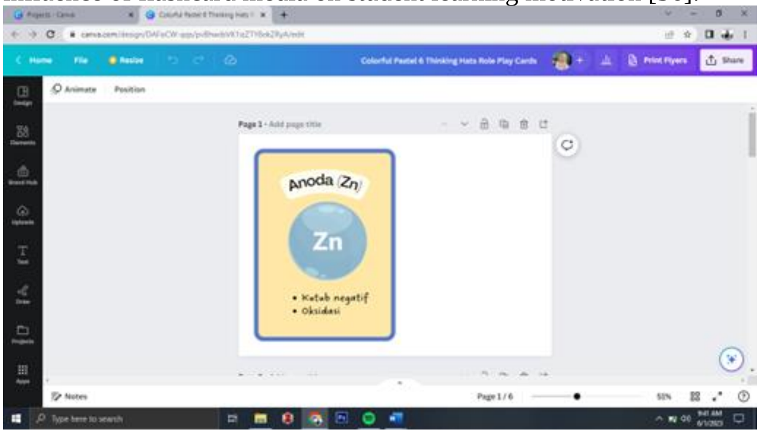
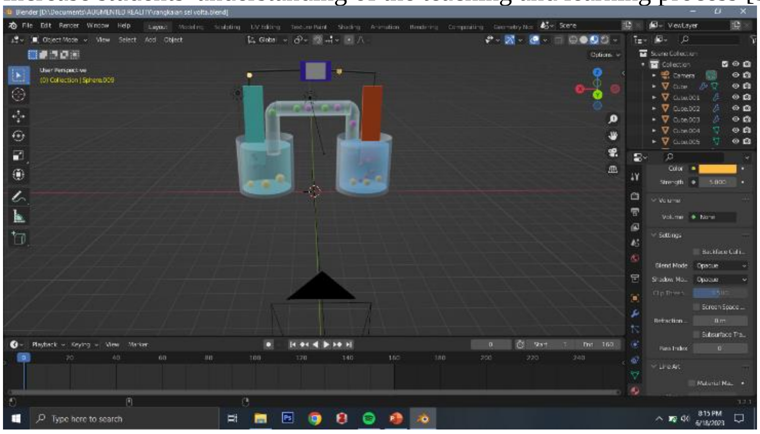
3.1 Analysis

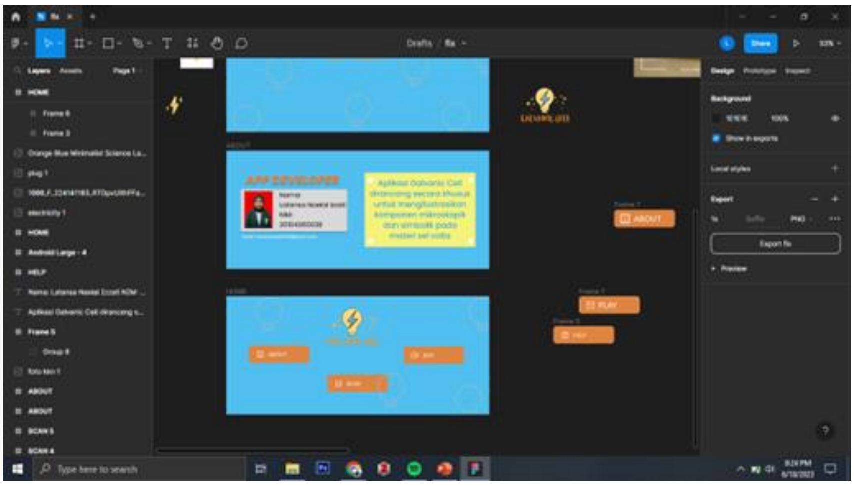
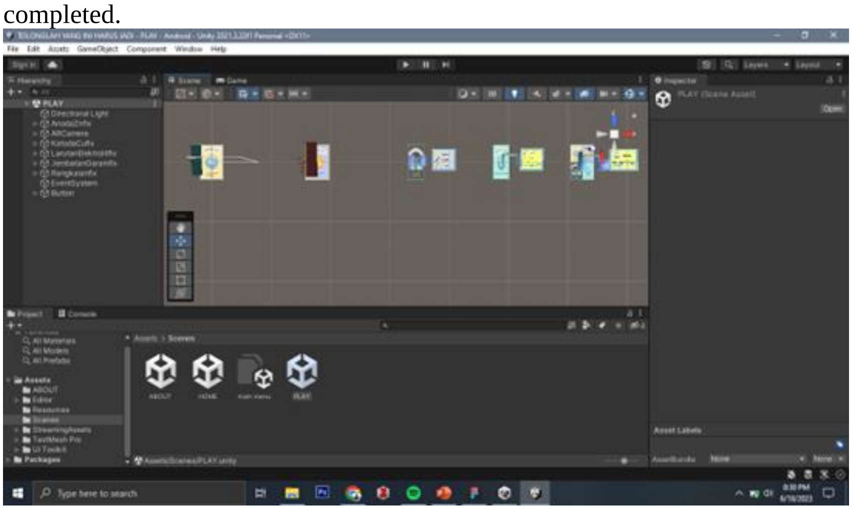
The analysis stage aims to determine the media design that will be made according to needs. At this stage, interviews were conducted with chemistry teachers to assess the need for learning media in schools. Based on interviews with chemistry teachers, information was obtained that the learning media used for voltaic cell material were textbooks from schools and videos on YouTube to understand the processes that occur in voltaic cells. Meanwhile, the practice uses batteries to discover its application in everyday life. The weakness of the learning media used is that it cannot illustrate the sub-microscopic and symbolic components of voltaic cell material. Based on the interview results, learning media is needed to demonstrate sub-microscopic and symbolic elements.

3.2 Design

The design stage aims to produce an initial model based on the needs analysis results in the previous stage. The design stage is shown in Table 1.

Table 1. Design Stage

The Design Stage	Explanation
Create a flashcard design with the Canva website.	The design stage began by designing a flashcard as a marker to display a 3D design when scanned using the application. Varied flashcard designs can increase students' enthusiasm for learning. Several research results show the influence of flashcard media on student learning motivation [56]. 
Create a three-dimensional design with the Blender 3D application.	The three-dimensional design included voltaic cell components with sub-microscopic aspects. The selection of three-dimensional images aimed to increase students' understanding of the teaching and learning process [57]. 

Create the application UI design with the Figma website.	User Interface (UI) design functions to connect users with the applications created. The user interface design was made as simple as possible to make it easier for students. 
Develop the application with Unity software integrated with Vuforia.	At this stage, a storyboard for the learning media application was created to make it easier for researchers to determine the flow of the application to be completed. 

3.3 Development

The development stage developed the product after the design stage. This stage produced a product in the form of a Galvanic Cell application. The development of the Galvanic Cel application is presented in Figure 2.

Figure 2. HOME Menu

On the HOME menu, there are three buttons: the "PLAY" button, the "ABOUT" button, and the "EXIT" button. The "PLAY" button displays the AR camera that will be used to scan the marker. The "ABOUT" button displays the developer app and the page about the Galvanic Cell application. The "ABOUT" menu is presented in Figure 3.

Figure 3. ABOUT Menu

Marker scanning was done via the camera by returning to the "HOME" menu and then selecting the "PLAY" button to display the camera, which would scan the image on the marker. After scanning the marker using the camera in the Galvanic Cell application, a 3D image would appear. The "PLAY" menu is presented in Figure 4.

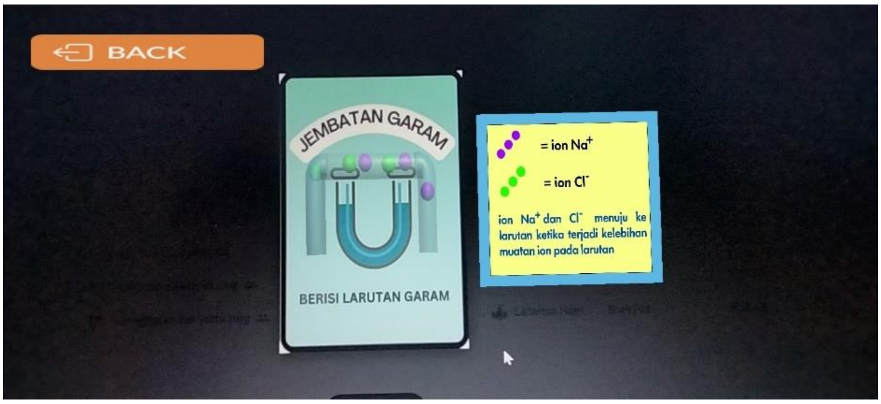


Figure 4. PLAY Menu

Four markers on each flashcard displayed 3D images, and a combined marker can display 3D images of a series of voltaic cells. First, an anode flashcard from Zn metal with a 3D design can be seen in Figure 5.

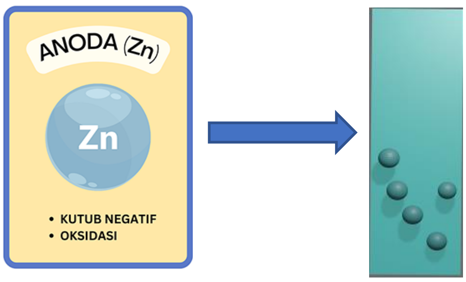


Figure 5. Anode (Zn) Flashcard

Scanning the anode flashcard using the Galvanic Cell application will display a 3D design of the anode. The 3D anode design depicts the oxidation process of Zn metal into Zn^{2+} ions. Second, the cathode flashcard is made of Cu metal with a 3D design, as seen in Figure 6.

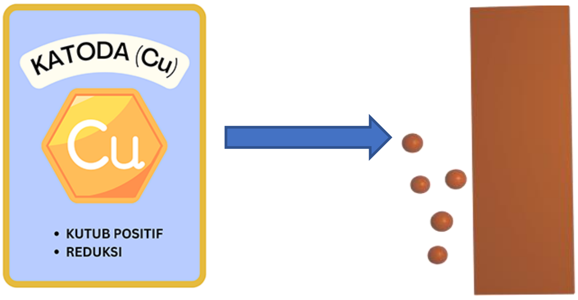


Figure 6. Cathode Flashcard (Cu)

Scanning the cathode flashcard using the Galvanic Cell application will reveal a 3D design of the cathode. The 3D cathode design depicts reducing Cu^{2+} ions to Cu metal. Third, the beaker flashcard contains the electrolyte solution ($ZnSO_4$ and $CuSO_4$), as shown in Figure 7.

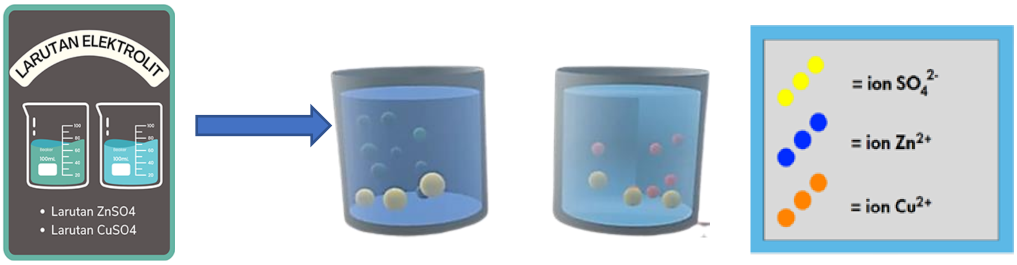


Figure 7. Electrolyte Solution Flashcard

The electrolyte solution flashcard scanned using the Galvanic Cell application will display a 3D design of the beaker containing the electrolyte solution. The 3D design aims to illustrate the submicroscopic components of the electrolyte solution in the form of ions. The blue balls represent Cu^{2+} ions, the yellow balls represent SO_4^{2-}—ions and the orange balls represent Zn^{2+} ions. Fourth, the salt bridge flashcard with a 3D design can be seen in Figure 8.

Figure 8. Salt Bridge Flashcard

The salt bridge flashcard scanned using the Galvanic Cell application will display a 3D design of the salt bridge. The design aims to illustrate the salt bridge's submicroscopic components in the form of ions. Green balls represent Cl^-——ions, while purple balls represent Na^+ ions. Figure 9 shows a combined flashcard with four previous flashcards and a 3D design.

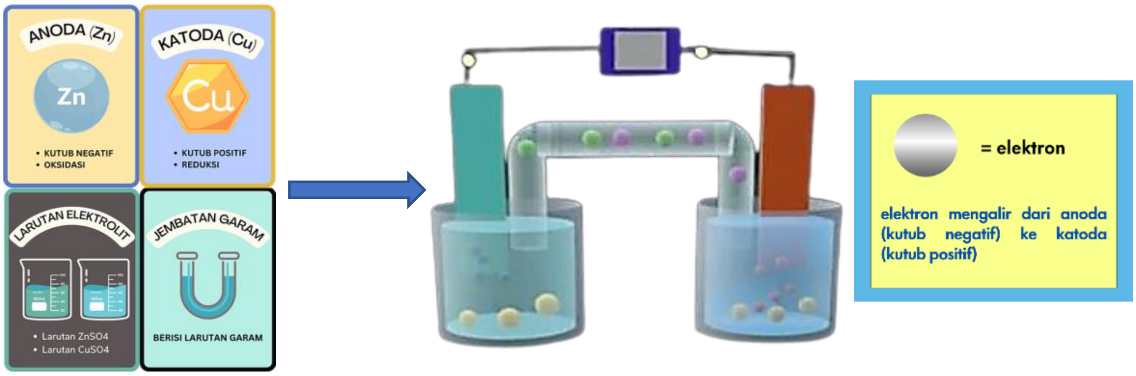


Figure 9. Flashcard for Voltaic Cell Circuit

Suppose anode flashcards, cathode flashcards, electrolyte solution flashcards, and salt bridge flashcards are arranged in such a way and scanned simultaneously via the Galvanic Cell application. In that case, they will produce a 3D design of a voltaic cell circuit. The 3D design of a voltaic cell circuit aims to illustrate all the components and processes that occur in a voltaic cell circuit. The voltaic cell reaction begins with Zn metal dissolving and producing Zn^{2+} ions and electrons. The large number of Zn^{2+} ions produced makes the solution positively charged. Cl^- ions from the salt bridge will neutralize the excess positive charge. Electrons from the anode flow to the cathode through a conducting wire. The electrons at the cathode are captured by Cu^{2+} ions, forming Cu deposits that stick to the cathode. The large number of Cu^{2+} ions that precipitate causes the solution to have a negative mutation. The solution is neutralized by Na^+ ions from the salt bridge. This process produces an electric potential difference that a voltmeter can measure by the resulting voltage.

The product was developed and then assessed by media experts, material experts, and reviewers. Media expert assessments included illustration, user-friendliness, system quality, flashcard display design, and AR. The material expert assessment included aspects of content and understanding of concepts. Meanwhile, the reviewer's assessment included learning materials, media, design, and implementation. Validation tests were carried out to determine the suitability of AR-based flashcard learning media and to obtain constructive feedback to improve the media.

3.4 Implementation

After receiving suggestions and input from experts and reviewers, implementation was carried out through product trials on ten twelfth-grade students at MAN 3 Bantul. The trial was conducted by giving flashcards, and the students installed the Galvanic Cell application on their Android phones. The teacher directed students to use AR-based flashcard media on voltaic cell material. Implementing media in learning aimed to determine how AR-based media helped students understand the concept of voltaic cell material. This media was specifically designed to illustrate voltaic cell components with submicroscopic aspects, such as anode and cathode reduction and oxidation reactions, ions in electrolyte solutions and salt bridges, and the movement of electrons in the voltaic cell circuit. The application for scanning markers on flashcards has a few menus to make it easier for students to use. The student response test covered the AR application, language, and 3D visuals.

3.5 Evaluation

One material expert, one media expert, and four reviewers used the Likert scale to assess the results. The results of the assessments of material experts, media experts, and reviewers are presented in Table 2.

Table 2. Product Quality Assessment Results

Validator	Assessment Aspects	∑ Skor	∑ Skor Ideal Maks	% Ideal	Category
Materials Expert	Contents	13	15	86.67%	Excellent
	Concept understanding	4	5	80%	High
Media Expert	Illustration	9	10	90%	Excellent
	User friendly	9	10	90%	Excellent
	System quality	15	15	86.67%	Excellent
	Flashcard display design	14	15	93.33%	Excellent
	AR	13	15	86.67%	Excellent
Reviewers	Contents	14	15	93.33%	Excellent
	Concept Understanding	4	5	80%	High
	Illustration	9	10	90%	Excellent
	User Friendly	9	10	90%	Excellent
	System quality	14	15	93.33%	Excellent
	Flashcard display design	14	15	93.33%	Excellent
	AR	13	15	86.67%	Excellent

Based on Table 2, the ideal percentage for material experts is 90% in the excellent category, media experts are 89.23% in the excellent category, and reviewers are 90.58% in the excellent category. Experts and reviewers provided high comments and suggestions to improve product quality, such as aspects of voltaic cell components that needed to be added. Researchers responded to this by adding an explanation regarding the ions found in the salt bridge and electrolyte solution to complete the explanation regarding the components of the voltaic cell. Experts and reviewers assess that the product developed presents the material systematically and that the language used is easy to understand so that it can motivate and help students understand the concepts of the material well. According to research by [58], [59], AR-based media can improve students' understanding, which shows that the use of expanded reality-based media is one of the factors that causes students to increase their understanding of the water cycle material.

The following process tests students' responses to AR-based flashcard media on voltaic cell material. The response test was conducted on 10 class XII students at MAN III Bantul by filling out a Google Form using the Guttman scale. The results of student responses are presented in Table 3.

Table 3. Results of Student Responses to Learning Media

Aspect	Criterion Number	Learners									
		1	2	3	4	5	6	7	8	9	10
AR App	1	1	1	1	1	1	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1	1
Language	2	1	1	0	1	1	1	1	1	1	1
	5	1	1	1	1	1	1	1	1	1	1
3D Visuals	3	1	1	1	1	1	1	1	1	1	1
	6	1	1	1	1	1	1	1	1	1	1
		6	6	5	6	6	6	6	6	6	6
Percentage		98.3%									

Student response tests include aspects of AR applications, the language used, and 3D visuals. The results of the response test that was carried out obtained a percentage of 98.3%. Based on the criteria for the student response test category, these results are included in the excellent category, so it can be concluded that AR-based flashcard media can help students understand the basic concepts of voltaic cell material. This is by research [31], which shows that using learning media can improve students' understanding of concepts. This shows that using varied and technology-based learning media can help students understand the concept of voltaic cell material.

In education, this research contributes to expanding the reference materials that can be used to enhance students' conceptual understanding. Utilizing AR in the development of learning media is also a positive step towards continuously improving the quality of education by leveraging technological advancements. Therefore, this research not only provides insights into media that can be used to enhance students' conceptual understanding but also harnesses technological advancements for learning.

4. CONCLUSION

The product developed in this research is flashcard media based on AR on voltaic cell material. The assessment results from material experts obtained an ideal percentage of 90% in the excellent category, media experts 89.23% in the very category, and reviewers 90.58% in the excellent category. Students responded positively to the product developed with an ideal percentage of 98.3%. Based on the assessment results and student responses, the developed product can be an alternative media to increase students' understanding of voltaic cell material. This research was only tested on a small group, so further research is needed to test AR-based flashcard media on a larger group to determine the product's effectiveness as a learning media in a class.

AUTHOR CONTRIBUTION STATEMENT

LNI contributed to conceiving and designing experiments, conducting experiments, analyzing and interpreting data, and writing articles. AK Contributed to improving and providing input on the research manuscript.

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