HYDROGEN
JURNAL KEPENDIDIKAN KIMIA
https://e-journal.undikma.ac.id/index.php/hydrogen/index

August 2024. 12(4)
e-ISSN: 2656-3061
p-ISSN: 2338-6487
pp. 844-854

Development of Augmented Reality Technology Integrated Learning Media on the Topic of Chemistry and Matter

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Article History
Received: 04-07-2024
Revised: 19-08-2024
Published: 31-08-2024

Keywords: learning media, augmented reality, chemistry and matter

Abstract
Augmented Reality (AR) technology allows interaction between the real world and objects in the virtual world in a three-dimensional form. With these advantages, AR will be a learning media that can increase students' enthusiasm for learning chemistry, especially on abstract chemistry concepts, and require the right learning media to visualize them. This type of research is Educational Design Research with the Plomp development model. The subjects of this study are UNP chemistry lecturers, chemistry teachers, and students at three senior high schools in Sumatera Barat. The object of this study is an augmented reality integrated learning media. The research instruments used were a needs analysis questionnaire, a validity test questionnaire, and a practicality test questionnaire. The data analysis technique uses the Aiken'V formula. The study results show that the developed learning media is included in the valid and practical categories with the validity values of content, construction, and quality respectively being 0.87; 0,85; and 0.85. Meanwhile, teachers' and students' average practicality score index results were 0.97 and 0.92. Thus, the learning media integrated with augmented reality technology in the chemistry concept for the E phase of SMA/MA chemistry has been successfully developed, validated, and practically used in learning.

How to Cite: Liza, W., & Guspatni, G. (2024). Development of Augmented Reality Technology Integrated Learning Media on the Topic of Chemistry and Matter. Hydrogen: Jurnal Kependidikan Kimia, 12(4), 844-854. doi:https://doi.org/10.33394/hjkk.v12i4.12230

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INTRODUCTION

The development of information and communication technology in the 21st century influences all aspects of life including education. The development of information and communication technology in the world of education has led to the emergence of innovations in educational goals and practices. The innovation aims to improve the quality and learning experience for students (Notanubun, 2019). One of the innovations that has emerged in the world of education as a result of the development of ICT is the presence of various forms of ICT-based learning media (Munti & Syaifuddin, 2020). These learning media include learning media using Canva (Sunarti, 2022), Powerpoint I-spring (Hanika & Guspatni, 2023), Flipped Classroom using Moodle (Fani & Mawardi, 2022), Augmented Reality and Virtual Reality learning media (Jang et al., 2021).

Augmented reality as an educational media has become a research trend lately. There are at least 989 pieces of literature from the Google Scholar database in 2018-2023 (Marlina et al., 2023). This happens because Augmented Reality as an educational media has many advantages, including increasing enthusiasm and learning independence for students (Fitria, 2023), and has proven effective in improving student learning outcomes (Fajari et al., 2023; Yamtinah et al., 2023). In addition, chemical learning media based on augmented reality technology has been proven to be effective in making students' synthetic mentality develop

(Supriadi et al., 2023), proven to be effective in improving students' abstract thinking skills (Apriani et al., 2021; Hikmah et al., 2022), and there was an increase in students' ability to understand multiple chemical representations (Ningrum et al., 2021).

Augmented reality technology is a system that allows interaction between the real world and objects in the virtual world in three-dimensional form in real-time (Chen et al., 2019). Thus, the use of Augmented Reality as a learning media will create an interesting and immersive learning atmosphere for students (Alzahrani, 2020). In chemistry learning, Augmented Reality technology helps students visualize abstract chemical concepts. One of the abstract concepts in chemical concepts is about the particles that make up matter. The particles that make up matter can be atoms, ions, or molecules. Chemical concepts at this level cannot be seen with the naked eye, so a media that can visualize them well is needed to understand these concepts. This also aims to avoid misconceptions in students.

Misconceptions often occur in almost all chemical concepts, including the topic of particles that make up matter (Rokhim et al., 2023). This is because students usually understand differently what the teacher explains (Hidayat et al., 2020). For this reason, augmented reality learning media can be a solution to equalize the different perspectives of teachers and students toward abstract chemical concepts (Pradana, 2020). Augmented reality technology as a chemistry learning media has many advantages, which have been proven in previous studies. However, in reality, the use of this technology in schools is still relatively rare (Fombona et al., 2022). This is supported by the findings obtained from the results of a preliminary study in three schools in West Sumatera, that chemistry teachers and students at this school don't even know about Augmented Reality technology.

The learning media that teachers have been using in the teaching and learning process are in the form of PowerPoint, printed modules, LKPD, and printed books facilitated by Kemdikbud. However, the use of these learning media is not enough to make students interested in learning. This is supported by findings in the field that as many as 74,14% of students at three schools in West Sumatera argue that some chemical concepts are easy and interesting to learn. It means that some other concepts are considered less interesting and difficult for students to understand. Therefore the focus of this research is to produce an integrated chemistry learning media Augmented Reality. The novelty of this study is that augmented reality integrated learning media is packaged in one interactive learning application, the type of augmented reality used markerless-augmented reality, and the learning media that has been designed has been adjusted to the latest curriculum which is kurikulum merdeka. This application is hoped to produce a fun and meaningful learning atmosphere to attract students' interest in learning.

METHOD

This type of research is Educational Design Research with a Plomp development model. This development model has three stages, namely the preliminary research stage, the prototyping stage (prototyping phase I-IV), and the assessment phase (Plomp & Nieveen, 2013). However, the focus of this research only reaches the stage of prototype IV formation, namely the production of learning media that is valid and practical. The preliminary research stage consists of several stages, including needs and context analysis, literature review, and conceptual framework development. The needs analysis stage aims to identify problems and what kind of media are needed in the field. At this stage, the researcher distributed a needs analysis questionnaire to chemistry teachers and Phase E students in three senior high schools in West Sumatera.

Context analysis is intended to identify problems obtained from the results of the needs analysis questionnaire. At this stage, an analysis of the Learning Outcomes (CP) is also carried out and then the learning outcomes are reduced to Learning Objectives (TP) which finally form the Learning Objectives Flow (ATP). In the literature review, the activities carried out are to search for various information or references and collect relevant theories needed for the development of learning media.

At the stage of developing the conceptual framework, the preparation of the main concepts related to the development of learning media is carried out. A conceptual framework is a series of theories and concepts resulting from a literature review and contextual analysis related to systematically connected research problem-solving.

The results of needs and context analysis, literature studies, and conceptual framework development became the basis for the development of the initial design of the learning application. This design is in the form of creating flowcharts and storyboards that can explain how the application flow runs. Furthermore, This initial design is used as a basis in the design of the prototype I, namely AR-integrated learning media in the form of an application that can be downloaded using an Android device. The prototype I was designed using several major software, including Unity 3D, Easy AR, and Blender 3D. Unity 3D is a cross-platform game development engine that can be used to create interactive 2D or 3D experiences, including video games, simulations, visualizations, virtual reality, or Augmented Reality. Unity 3D also allows developers to create applications for desktop computers, smartphones, or the web. In addition, it also supports a wide range of programming. For this study, the C# programming language was used through Microsoft Visual Studio 2022. Easy AR is a markerless AR development platform. This stage is done by integrating Easy AR into the Unity project. This is possible because Easy AR does have support from many platforms, such as iOS, Android, Windows, and Unity. Blender 3D is an open-source three-dimensional project creation software that can be used for modeling, animation, and rendering. In this study, Blender 3D is used to create 3D objects. Examples are making 3D objects from the particles that make up matter in the form of atoms, molecules, and ions, or making 3D objects from elements and compounds at the submicroscopic level.

Furthermore, a self-evaluation of prototype I was carried out so that prototype II was produced. Self-evaluation is carried out using a checklist instrument on the functionality as well as the components of learning media. At the stage of prototype III formation, a formative evaluation of prototype II is carried out in the form of expert evaluation and one-to-one evaluation. After that, revisions were made to produce prototype III, which is a valid augmented reality integrated learning media. Furthermore, prototype III was again evaluated through small group evaluation. The results of this evaluation will produce prototype IV, which is a practical learning media.

The research was conducted in FMIPA UNP and three senior high schools in West Sumatra. The subject of the research is UNP Chemistry lecturers and chemistry teachers as validators, and students as individual assessors. Data collection instruments used a needs analysis questionnaire and, a validity and practicality questionnaire. The validity and practicality of data analysis techniques using Aiken's V formula are described as follows.

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

$$s = r - l_0$$

Aiken's V formula where V is the consensus index by the expert (Aiken's value V; s is the score set by the expert minus the lowest score of the category (s = r – l0, where r = the score of the expert's chosen category and l0 = the lowest score in the scoring category); n is the number or number of experts who give the rating; and c is the number of categories chosen by the expert.

Validity and practicality questionnaire using differential semantic scales (1, 2, 3, 4, 5, 6, 7). According to Issac and Michael (1984) one of the goals of differential semantic scales is as an attitude scale centered on affective aspects or evaluative dimensions, such as "agree-disagree", "fast-slow", or "good-bad"(Prihadi, 2019).

This study uses six validators, three teachers, and nine students as assessors of the practicality of learning media. The categories of validity and practicality can be seen in the table 1.

Table 1. The validity and practicality category validators (Aiken, 1980).

Number of Validators/ Assessors	V score	Category
3	$V \leq 0.89$	Invalid/ Impractical
	$V \geq 0.89$	Valid/ Practical
6	$V \leq 0.79$	Invalid/ Impractical
	$V \geq 0.79$	Valid/ Practical
9	$V \leq 0.70$	Invalid/ Impractical
	$V \geq 0.70$	Valid/ Practical

RESULTS AND DISCUSSION

Preliminary Research

Preliminary research is used as the basis for the development of Augmented reality technology integrated learning media on the topic of chemistry and matter for chemistry phase E. The results of the preliminary research are described as follows.

Need and Context Analysis

At this stage, the activities carried out include needs and context analysis, literature studies, and the development of a conceptual framework. Based on the results of the needs analysis in the form of distributing questionnaires to teachers and students in three schools, it was found that the learning media commonly used by teachers was quite varied and contained pictures, animations, and videos. However, it is still lacking in terms of delivering three levels of chemical representation. The chemical representations shown are only at the macroscopic and symbolic levels. The interconnection between the macroscopic, submicroscopic, and symbolic levels is important for learners. The involvement of the three levels of chemistry representation in the chemistry learning process has a positive influence on students, including increasing concept understanding, reducing cognitive burden, reducing misconceptions, and reducing students' assumptions about chemistry as a difficult subject (Permatasari et al., 2022).

In addition, the learning media used by teachers has not fully made students interested and actively involved in the learning process, This is in line with the findings in the results of the questionnaire analysis distributed to students where students think that only some chemical concepts are easy and interesting to learn and the media provided by teachers is not enough to help students imagine chemical concepts. To overcome this problem, innovative learning media is needed that can attract interest and make students actively involved in the learning process. Chemistry learning materials that are packed with innovation and interest can help students learn chemistry efficiently and be actively involved in learning (Sinaga et al., 2019).

Another finding obtained at the needs analysis stage is the school's policy that permits students to use *smartphones* during the learning process. However, the use of *smartphones* in the learning process has not been utilized optimally. This is an opportunity to develop learning media integrated with Augmented reality technology as a learning media in schools. The results of the needs analysis provide an overview of what kind of media teachers and students need. Based on the results of the analysis of the problems that have been carried out, it is concluded that the learning media to be developed is expected to increase learning interest, activity, and learning media that contain three levels of chemical representation. Context analysis is carried out on the Chemistry Learning Outcomes (CP Chemistry) and then these learning outcomes are reduced to Learning Objectives (TP) which ultimately form the Learning Objectives Flow (ATP).

Literature Review

Literature reviews are carried out to obtain various information or references needed in the development of learning media. This stage aims to find out whether in previous research augmented reality integrated learning media was successfully developed and suitable for students to use as a learning media. The development of chemistry learning media based on Augmented Reality (AR) technology produces learning media that is valid, practical, and effective and makes students' synthetic mentality develop (Supriadi et al., 2023). Chemar (Chemistry Augmented Reality) on the periodic system of effective elements improves students' abstract thinking skills(Hikmah et al., 2022). The development of augmented reality-based learning media on the hydrocarbon concept has succeeded in improving students' ability to represent multiple (Ningrum et al., 2021). AR facilitates students in exploring chemical materials (Yamtinah et al., 2023). The chemistry module with AR integration is practical and declared feasible to be implemented in chemistry learning (Almubarak et al., 2021). AR-based chemistry modules are valid, practical, and effective in learning (Ramadani et al., 2020). Chemistry Structure Sheet as an Augmented Reality-Based Chemistry Learning Media on Atomic Structure Materials is practical and feasible to be used in the teaching and learning process by educators and students (Aris et al., 2020).

Development of The Conceptual Framework

The results of the needs and context analysis and literature review are developed into a conceptual framework, flowchart, and storyboard. The conceptual framework contains concepts related to the development of learning media. Flowcharts and storyboards are used as a reference at the prototype formation stage.

Prototyping Phase

At this stage, four prototypes were produced, each of which was improved so that a valid and practical prototype was obtained in the form of AR-technology integrated learning media on the topic of chemistry and matter for chemistry phase E that are ready to be tested for their effectiveness. Learning media is designed to be as attractive as possible but still follow visual principles (Clark & Lyons, 2011). The visual appearance of learning media is not only for decorative functions, but is designed by considering its surface features (visual characteristics), communication functions, and interactions with the learning process (Clark & Lyons, 2011). If the learning media is designed following visual principles, the resulting learning media will play an important role in the learning process, including providing concrete references, making abstract concepts concrete, motivating students, attracting students' attention, helping students remember learning and reducing cognitive load (Smaldino & Lowther, 2012).

Prototype I

Prototype I is an integrated learning media in the form of an application. The app can be downloaded and installed on Android devices. The components contained in the learning media developed consist of a cover page (figure 1) and a main menu (figure 2). Each page comes with a variety of clickable buttons with their functions.

Figure 1. Cover page

Figure 2. Main menu page.

On the main menu, there are several active buttons, including, exit buttons, download buttons, instruction buttons, buttons about the application, curriculum buttons, material buttons, and evaluation buttons. Exit button to exit the app. The download button contains the manual book. The material is delivered in several ways, such as with guiding questions, with Augmented reality, pictures, videos, and with quizzes. Augmented reality displayed in the media learning is in the form of three-dimensional animation delivered in three levels of chemical representation (Figure 3). Interconnection between the macroscopic level, submicroscopic, and symbolic is important for students so that they can understand the concept of chemistry in its entirety (Permatasari et al., 2022). This will also reduce the potential for misconceptions in students in understanding abstract chemical concepts (Suparwati, 2022).

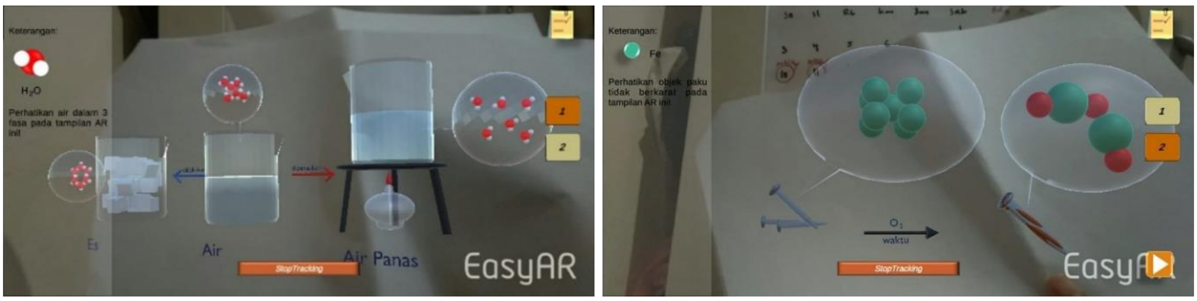

Figure 3. Augmented reality displayed

Quiz questions consist of several types of questions, such as multiple-choice questions, word drag, drop-down, and multiple responses. In addition, every sub-material that students complete will receive feedback. With the existence of many types of questions in the learning media, this learning media becomes very interactive. Interactive media learning can increase students' enthusiasm for learning (Arman & Debora, 2022).

Prototype II

In the formation of prototype II, self-evaluation is carried out. This evaluation is to ensure the completeness of the learning application in terms of its physical appearance (Plomp & Nieveen, 2013).This evaluation is in the form of a checklist of functionality and components of the learning media to find out the completeness of prototype I. In this case, there are errors in the display of the learning application, namely on the instructions page and the developer profile. Furthermore, revisions were made to prototype I based on the results of self-evaluation so that prototype II was produced.

Prototype III

At the stage of prototype III formation, an evaluation of the second prototype is carried out by an expert review and a one-to-one evaluation. Furthermore, revisions were made to prototype II so that prototype III was produced. The results of the review by experts and one-on-one evaluation are as follows.

Expert Review

This assessment was carried out through a validity test of the teaching media integrated with Augmented reality technology on the concept of chemistry for phase E. The results of the validity test can be seen in Table 2.

Table 2. Results of the Validity Test of Learning Media

Validity	V	Category
Content	0,87	Valid
Construct	0,85	Valid
Quality	0,85	Valid

Based on the content validity, construct and quality test tables obtained consecutive average values of V are 0,87; 0,85; and 0,85 with valid category.

The validity of the content to compare the suitability of the learning media with the subject matter and is scientifically correct (Plomp & Nieveen, 2013). The validity of the content shows the suitability of learning in the media with the current curriculum and by its chemical science. Based on the results of the assessment by the validator, several revisions were made, including the initial material introduction where the material content could not lead students to find the concept of the material itself, as well as correcting the information on one of the Augmented reality pages. Based on the results of the data analysis, the average value of content validity was 0.87. This number means that the learning media is valid and follows chemical science.

Construct validity aims to see each component of the media connected consistently and logically (Plomp & Nieveen, 2013). In the validation of the construct, several revisions were made, including deleting and replacing images that were not suitable, and changing the type of word drag-type quiz question to a drop-down question type. Based on the results of the data analysis, the average value of construct validity was obtained at 0.85. This means that the learning media is valid and well-designed.

The validity of technical qualifications is carried out to ensure that the features in the learning media function properly. These features include start, tracking, stop tracking, zoom, and transform. Based on the results of the data analysis, the average value of validity of technical qualifications was obtained at 0.85 with valid categories. However, there are suggestions from validators regarding the application file format. The advice given is that the application file format is not in .apk form. Due to the limitations of the author, this has not been fixed. This learning media in terms of content, construction, and quality have gotten good results.

However, this learning media still needs to be improved in some parts. Based on the assessment given by the validator, there are several improvements, including improving one of the material content to be in accordance with the learning objectives (TP), correcting some wrong quiz questions, and correcting one of the AR so that it is in accordance with the rules of chemical science. Furthermore, revisions were made to prototype II so that prototype III was produced.

One-to-One Evaluation

A one-to-one evaluation was carried out by three-phase E students at SMAN Z at Sijunjung. The selection of students is based on the different levels of cognitive ability of students. Students are selected based on high, medium, and low cognitive abilities. This evaluation aims to find out the students' response to the learning media that is being developed and to see how students are interested in learning. The one-to-one evaluation that has been given to students shows a positive response. The learning media developed is good and interesting and can help students understand every concept that exists with the help of animation or 3D objects, videos, images, and various types of interactive quizzes. The results of the one-to-one evaluation were used as a reflection for the improvement of prototype II.

Prototype IV

At this stage, prototype III was evaluated through small group trials and chemistry teacher responses. The goal is to find out the practical value of prototype III. This practicality test was carried out by nine phase E students and three chemistry teachers. The practicality of learning media is seen based on the ease of use of media (Plomp & Nieveen, 2013). The results of the practicality test by teachers and students can be seen in Tables 3 and 4.

Table 3. The Results of the Practicality Test of Learning Media from Teachers

Aspects	V	Category
Ease of use	0,97	Practical
Colonization time efficiency	0,95	Practical
Benefit	1,00	Practical
Average value index	**0,97**	**Practical**

Table 4. The Results of the Practicality Test of Learning Media from Students

Aspects	V	Category
Ease of use	0,95	Practical
Colonization time efficiency	0,90	Practical
Benefit	0,93	Practical
Average value index	**0,92**	**Practical**

The results of the analysis of data on the practicality of learning media by teachers and students when reviewed from the aspect of ease of use resulted in an average score index of 0.97 and 0.95 respectively with each in the practical category. This means that the learning media that has been developed is easy to use, easy to understand, the media design is attractive, 3D images and objects are displayed clearly, and the learning media can be used repeatedly. The results of the analysis of data on the practicality of learning media by teachers and students when viewed from the aspect of learning time efficiency resulted in an average score index of 0.95 and 0.90 respectively with each in the practical category. This means that Augmented reality integrated learning media makes learning time more effective and efficient and can be accessed anytime and anywhere.

The results of the analysis of data on the practicality of learning media by teachers and students when viewed from the aspect of its benefits to the learning process resulted in an average score index of 1.00 and 0.93 respectively with each in the practical category. This means that Augmented reality integrated learning media can increase students' interest in learning, motivate students to learn, and help students discover chemistry concepts independently. Based on the average index value of the practicality test both tested teachers and students, the results were obtained that the learning media developed in the practical category.

CONCLUSION

Based on the research that has been conducted, it can be concluded that the integrated learning media of augmented reality technology has been successfully developed. The results showed that AR-technology integrated media learning media on the topic of chemistry and matter for chemistry phase E is valid and practical to use in learning. Augmented reality integrated learning media that is packaged very interactively makes this learning media as an alternative to increase students' enthusiasm for chemistry learning. In addition, learning media that also contains multiple chemical representations can help students understand abstract chemical concepts.

RECOMMENDATION

Based on the research that has been carried out, it is hoped that the next researcher can continue this research to conduct an effectiveness test on the AR-technology integrated media learning media on the topic of chemistry and matter for chemistry phase E.

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