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Research Artikel

DEVELOPING THE VIRTUAL ATOMS AR LEARNING APP FOR ANDROID

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Abstract
The development of technology has a significant impact on education, one of the innovative learning methods that can be applied in the digital era is augmented reality. The topic of atomic structure is one of the difficult subjects to understand and needs visualization, so the development of augmented reality learning media is required. Augmented reality developed for the atomic structure topic is tailored to the needs of students, accompanied by sample questions, and materials, and can be accessed online or offline using Android. This research aims to determine the feasibility, including the validity, practicality, and effectiveness of augmented reality learning media on the atomic structure topic in an Android application. This development research method uses the ADDIE model of Analysis, Design, Development, Implementation, and Evaluation. The research instruments include validation sheets, interview guidelines, questionnaires, and pre-test & post-test exams that have been validated. The research sample consists of 90 eighth-grade students from SMPN 2 Merauke. The final result of this developmental research is a product in the form of an augmented reality atomic structure learning media application that is suitable for use and can be accessed through Android without an internet connection. The feasibility of the developed learning media is based on validity, practicality, and effectiveness. The material validation result is 82% (very valid) while the media validation is 80% (valid). The practicality test results average 84% (efficient). The effectiveness test results with an N-gain of 0.76 (high) and a percentage of 76% fall into the effective category. Therefore, it can be concluded that the product is suitable for use and there is an improvement in student understanding using augmented reality learning media.

Keywords*: Augmented Reality; Android; Learning Media; Atomic Structure.*

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INTRODUCTION

The transformation of learning is currently taking place rapidly, as evidenced by all digital-based fields and the field of education is no exception. The paradigm shift in 21st century education certainly follows technological developments (Nasution et al., 2023). The learning process of Education 4.0 is focused on the use of technology so that every individual can be responsive and able to adapt to changes and technological innovations (Syam et al., 2023). The era of revolution that is now shifting from Education 4.0 to Education 5.0 needs to be addressed wisely, especially regarding the use of technology, to improve the quality of human resources. One way to improve the quality of human resources is with good science education. A good understanding of science has an impact on students' courage and independence in making decisions to find answers to science problems in daily activities (Sumanik, 2022). Therefore, to increase students' interest in science, innovation in the learning process is needed. In addition, the importance of technology integration in meeting learning needs in the modern era, including science materials (Azrai et al., 2024).

Science material for students is difficult material, this is obtained based on interviews conducted with students and teachers at SMPN 2 Merauke. Based on these interviews, it was also found that students could not understand science material well, especially atomic structure. The characteristics of the material are complex and abstract so it needs visualization to clarify the atomic structure material. So far, the use of learning media at SMPN 2 Merauke is still limited and less varied, which affects the learning outcomes of students. Students will be helped by choosing the right learning media, and help increase motivation and learning outcomes (Sumanik et al., 2021). Therefore, it requires interactive learning media that can describe objects to be more real to support the success of learning.

The selection of learning media is based on the needs and development of the times so that the need for innovation integrates the use of technology. The use of technology in the learning process can improve critical thinking, be effective, and innovative and the learning environment becomes fun (Suhartini & Haerani, 2022). Atomic structure material itself is not enough with lectures but needs visualization of objects to make it easier to observe. This is because it is difficult to imagine the real form of the object being explained or the difficult of students visualizing an object. Learners tend to memorize concepts, making it difficult to relate atomic structure material at the microscopic, symbolic, and macroscopic levels. On the other hand, the atomic structure itself is difficult to observe with the naked eye, so it needs tools such as props or replicas. The use of technology-based learning media is an effective step in delivering learning materials (Maulid et al., 2024).

Augmented Reality (AR) technology is the right solution for clarifying atomic structure material. The use of AR is very helpful and is a valuable technology because it can increase knowledge (Sommerauer & Müller, 2014). AR technology is in demand in various sectors around the world, including education (Avila-Garzon et al., 2021). Augmented reality is the integration of virtual images with the help of technology so that it seems as if the image is real (Sa'adi et al., 2023). There have been many researches that use AR in chemistry. Augmented reality technology in chemical materials, one of which is carbon bonds, has pedagogical implications for the 3D, physical, cognitive, and contextual learning process and makes students more active and motivated (Silva et al., 2023).

Augmented reality technology is a merger of the real world with virtual 2D or 3D projected in the real world, with the help of media such as Android smartphones. Augmented reality utilizes various features on virtual objects that can be visualized in the real world (Alper et al., 2021). To display the virtual object, a marker is used on each object that will be projected. The image contained in the marker is a 3D printed object so that when the application is directed at the marker, the 3D object will look real as if it appeared from the image. The advantages of AR are interactive learning media, is effective, can be widely implemented, simple object modeling, is more

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economical, and is easy to operate (Mustaqim & Kurniawan, 2017).

There have been many previous studies that utilize AR technology in learning and have proven effective in improving learning outcomes. The use of AR in science learning can improve learning outcomes, this application is used online which is downloaded on the Play Store (Fakhrudin & Kuswidyanarko, 2020). On the other hand, the use of AR shows significant learning effects for students with low learning achievement, and the use of AR correlates with evaluation (Cai et al., 2014). Learning media on chemical molecular materials that utilize AR technology can increase students' interest and understanding so that students become easier to learn (Kartini & Lukman, 2024). Augmented Reality can support the learning process in learning chemical reaction materials, but the development of this AR application is not equipped with material and sample questions (Setiawan et al., 2019). Starting from previous research, the gap in this research is the use of AR which is still limited to certain materials, and the development of AR applications that have not been equipped with material and sample questions, on the other hand, the application requires a network. Based on this, the novelty of this research is to develop AR learning media on atomic structure material which is equipped with sample questions, material, and evaluation, on the other hand, the distribution of AR media can also use the network or without a network. Based on this, this research is important because of the use of learning media according to the demands of the 21st century and the trend of using augmented reality in education as learning that can make it easier for students to visualize the material.

The ease of use of AR learning media through Android is the right choice because all students have Android. So that students can learn anytime and anywhere with the help of AR technology in Android applications. On the other hand, offline utilization of AR Android applications is needed, given the unstable internet access in the Merauke area. Therefore, the development of AR learning media on atomic structure material using Android is needed to help students more easily understand the material well.

METHOD

The Research & Development (R&D) adaptation of the ADDIE model includes Analysis, Design, Development, Implementation, and Evaluation (Sugiyono, 2018). The subjects of this research trial are 90 students of SMPN 2 Merauke grade VIII. This research instrument is in the form of validation sheets, interview guidelines, questionnaires, pretest, and posttest questions on atomic structure material that has been validated. The atomic structure pretest and posttest questions were made in the form of essays with 10 questions, with indicators of competency achievement, namely the concept of atoms, the concept of atomic structure, and the development of atomic theory. This study aims to determine the feasibility of AR learning media products through validity, practicality, and effectiveness tests.

The validity test can be calculated using the following formula:

$$P = \frac{\sum F}{\sum N} \times 100$$

Information:

P = Percentage of each respondent

$\sum F$ = Number of answers per respondent

$\sum N$ = Maximum number of respondents

The results of the percentage calculation are interpreted into 5 criteria 81%-100% very valid, 61%-80% valid, 41%-60% quite valid, 21%-40% invalid, and 0%-20% very invalid (Sugiyono, 2018).

The practicality test is based on a Likert scale with 5 categories, namely Strongly Agree (SS), Agree (S), Neutral (N), Disagree (TS), and Strongly Disagree (STS). The results of the calculation of the percentage of practicality are interpreted into 5 categories, namely 81%-100% very practical, 61%-80% practical, 41%-60% quite practical, 21%-40% not practical, and 0%-20% very impractical (Sugiyono, 2018).

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The effectiveness test can be calculated using the Normalized Gain (N-Gain) formula according to (Hake, 2002) as follows:

$$\text{N Gain} = \frac{\textit{Average Posttest Score} - \textit{Average Pretest Score}}{\text{Average Ideal Score} - \text{Average Pretest Score}}$$

The results of the Gain score are divided into 3 criteria, namely N-Gain < 0.3 low, 0.3 < N-Gain <0.7 Medium, and N-Gain > 0.7 high category. Then the N-Gain value is categorized in the interpretation of effectiveness, there are 4 criteria, namely <40 is not effective, 40-55 is less effective, 56-75 moderately effective and >76 is effective (Hake, 2002).

RESULTS AND DISCUSSIONS

This research uses the five stages of the ADDIE model which consists of the following:

Analysis Stage

This analysis stage includes student needs analysis and material analysis, which is carried out through a process of observation and interviews with science subject teachers and class VIII students. Based on observations and needs analysis interviews, information was obtained that teachers have not maximized the use of tecnology-based learning media that can visualize 3D objects in learning. The learning media used by teachers are still limited such as textbooks, PowerPoint, learning videos from YouTube, PDFs downloaded from the internet, and props made by the teacher himself. Chemistry material requires learning media to help clarify the material. Midak et al., (2021) explained that chemistry material requires visualization using 3D objects so that students better understand processes, phenomena, and atomic structures.

Based on interviews with students, data was obtained that several materials were considered difficult for students, one of which was atomic structure. The analyzed atomic structure material was in accordance with the syllabus and lesson plan at SMP Negeri 2 Merauke. Atomic structure materials require visualization in real life, so the integration of technology to display an image of atoms is needed. This is in line with previous research that the use of *augmented reality* (AR) can support the learning process, especially the visualization of chemical concepts (Herman et al., 2022).

Design Stage

This second stage is the stage of designing the atomic reality structure product to be developed. The preparation of this learning media includes:

a. Concept Preparation

Based on the learning objectives and Competency Achievement Indicators that have been determined, the next step is the preparation of the concept of reality atomic structure learning media. The preparation of this concept is adjusted to the learning process in the classroom. This aims to achieve the learning objectives and cumulative achievement index.

b. Media Selection

The right selection of learning media is needed for understanding the material (Sumanik et al., 2023). The concept of reality atomic structure learning media combines various kinds of assistance applications. The process of preparing the atomic reality structure includes designing application layouts and markers using Canva, designing 3D objects using Blender 3D, and designing AR media using Unity and Vuforia engines. The AR creation process combines several applications including the Unity 3D game engine and the Vuforia platform, unity to create games and 3D content, while Vuforia brings up objects on smartphones (Imbert et al., 2013). The object that appears in the image is called an AR Marker. AR Maker is a patterned image that will be read through a smartphone to display virtual objects (3D). There are four markers, namely Dalton, thompson, bohr, and Rutherford atomic model markers. The markers that have been made can be seen in Figure 1.

c. The selection of references and preparation of learning media.

The selection of references is very important for this learning media to be effective. In fact, by choosing the right references, it can design effective and interesting AR, this is because it is based on systematic reviews and meta-analyses (Buchner & Kerres, 2023). The references used include e-books, books, journals, proceedings, theses, and dissertations. The material on atomic

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structure developed includes the definition of atoms, and atomic theories namely Dalton, Thomson, Bohr, and Rutherford's atomic theories which are equipped with sample questions.

Figure 1. Marker

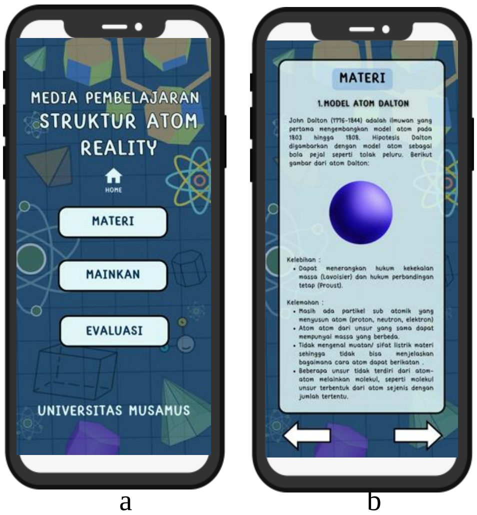
Development stage

The development stage includes:

a. Preparation of learning media augmented reality atomic structure

The development stage starts with the preparation of materials, evaluations, and markers using Canva. The development of this AR media starts from the process of creating 3D objects using the Blender application. Furthermore, it uses the use of Vuforia Engine as a marker detection to bring up 3D objects. A marker is an image that will be scanned by Android to bring up 3D objects. The use of applications helps in the application of design using blender applications to create 3D objects and Vuforia Engine so that markers can be read.

The main application in the research is Unity used to produce Android-based applications. The following is a display of the AR application of atomic structure learning media on the main page which consists of material, play, and evaluation menus. The material menu contains material related to atoms, Dalton, Thomson, and Bohr atomic theories, and quantum mechanical theory accompanied by examples of questions. On the play menu is an augmented reality menu by scans markers that have been printed to display 3D objects. The evaluation menu contains practice questions. The following is the development of the application of the atomic structure reality main page and material menu.



a b

Figure 2. a Main Page of the Atomic Structure Reality Learning Media Application, b. Content Menu Page

a b

Figure 3. (a) Example of Dalton atomic matter Questions on the Material Menu; (b) Evaluation Menu

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In this atomic structure learning media application, there is a play menu in the form of a marker scan that will display 3D objects. So it is necessary to prepare a marker that has been printed to make it easier to scan. The following is an atomic structure learning media that has been scanned markers so that it displays a 3D form can be seen in Figure 4-7.

Figure 4. Augmented Reality Dalton Atom Model

Figure 5. Augmented Reality Thomson Atom Model

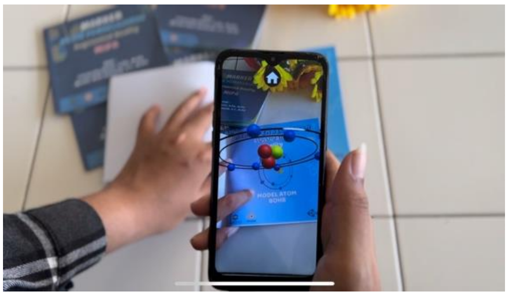

Figure 6. Augmented Reality Bohr Atom Model

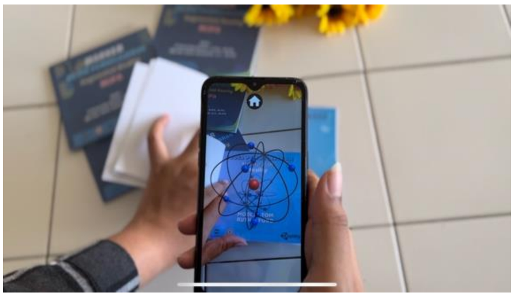

Figure 7. Augmented Reality Rutherford Atom Model

b. Validation of Research Instruments

All instruments used have been validated in advance by 2 material expert validators and 2 media expert validators. Material expert validators are 2 lecturers majoring in Chemistry Education at Musamus University. Media expert validators are 2 lecturers majoring in Informatics Engineering at Musamus University. The validation results can be seen in Table 1 as follows:

Table 1. Validation Test Results

Validation Test	%	Category
Material Validation	82	Very Valid
Media Validation	80	Valid
Validation of Teacher Response Questionnaire	85	Very Valid
Student Response Questionnaire Validation	81	Very Valid
Pretest-Posttest Validation	88	Very Valid

Suggestions and input from validators have been made. The validator's improvements are as follows:

1. Revision of the material validator: examples of problems need to be added, and an explanation is added at the beginning of the material.
2. Revision of the media validator: adding back and home navigation buttons in the material section; and adding a home button to play AR.
3. Revision of questionnaire validator: combining similar statements, clarifying sentences in a statement, changing some statements to be more appropriate to use, and paying attention to errors in word writing.
4. Revision of question validator: add questions to describe atoms and atomic structure.

The above revisions have been improved according to the validator's direction. Revisions were made 2 times. Furthermore, the learning media for atomic structure reality can be used at the implementation stage. This is in line with Mashami et al., (2021) AR technology that has been declared valid in chemistry learning can be implemented so that it can improve critical thinking skills. AR learning media is a technology that is very suitable for use in atomic structure chemistry material. Because of its advantages, it combines the virtual world and the real world so as to create a breakthrough in learning innovation. This opinion

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is also supported by (Ardian et al., 2021) which states that the application of applications using AR technology in chemical materials can be used as a new innovation in interactive learning media. The use of AR is basically very helpful for students because they need visualization in learning to remember more easily (Macariu et al., 2020).

Implementation Stage

This stage is the media trial stage to determine practicality and effectiveness.

a. Practicality Test

The small-scale trial or practicality test was conducted by 2 teachers and 30 students of class VIIIE. The results of the practitioner test can be seen in Table 2 below:

Table 2. Practicality Test Results

Practicality Test	%	Category
Teacher Response Questionnaire	84	Very Practical
Student Response Questionnaire	84	Very Practical
Average	84	Very Practical

Based on the practicality test, the data obtained that the AR learning media of atomic structure is very practical to use. This is in line with research (Pradana, 2020) that the use of AR helps students in achieving success in the learning process and teachers can help deliver material more effectively. The use of AR learning media helps students in thinking critically in solving problems. This is supported by Untari et al., (2022) the use of AR technology affects problem-solving skills. The use of AR learning media is effective in that it makes students more active. Reinforced by the opinion of Hardiyanti et al., (2020) The use of AR which can display 3D objects makes students more active in learning because learning while playing. AR technology in education can help in improving academics, motivation, and acceptance of the use of technology in chemistry materials (Silva et al., 2023).

Based on the results of the small-scale trial, revisions were made to the AR learning media atomic structure according to the input from the practitioner's response. The improvements include adding material related to the explanation at the end of the material why atomic theory has changed and adding an explanation of the quantum mechanical atomic theory.

b. Effectiveness Test

After the improvement, large-scale trials were conducted in two classes VIII K and VIII C with a total of 60 students. The large-scale trial begins with the administration of the pretest followed by the learning process using the atomic structure reality learning media. Learning ended with giving posttest. Furthermore, the analysis of student completeness is carried out, the indicator of completeness based on the minimum completeness criteria value is 75. The results obtained after learning using the atomic reality structure are that there is a significant increase in students above the minimum completeness criteria. The increase in student learning outcomes is calculated using the normalized gain (N-Gain) formula, the results of the N-gain calculation can be seen in the following Table 3.

Table 3 N-gain Results

Effectiveness Test	Information	Category
N-Gain	0.76	High
%Effectiveness	76%	Effective

Based on the N-gain results, the AR learning media of atomic structure is effective, as evidenced by the increase in student learning outcomes after using AR learning media of atomic structure accompanied by sample questions. The application of AR chemistry accompanied by worked examples helps in the learning process and overcoming complex information becomes easier (Elford et al., 2023). The increase in student learning outcomes is due to the use of AR technology that can stimulate the imagination to feel the existence of virtual objects directly. In line with this opinion, Padang et al., (2022) explained that the application of AR media can improve learning outcomes. On the other hand, the use of AR also provides motivation for students. Bau et al., (2022) the use of AR learning media on atomic structure makes it easier for students to understand the material and students become motivated. The same thing is also explained by Nurillah et al.,

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(2023) there are significant differences before and after learning using AR learning media in chemistry material. Augmented Reality has the potential to significantly improve teaching standards in education (Wilkins et al., 2024). Therefore, AR learning media provides a new color in the world of education to continue to be developed so that students better understand complex materials such as chemistry.

Evaluation Stage

The last stage of evaluation of the product is the application of AR learning media of atomic structure. This product is assessed from the validation stage to implementation. The final revision is done according to the practitioner's suggestion. Overall, the atomic structure AR learning media product is feasible to use. The development of reality atomic structure learning media combines several vuforia, unity, and blender applications that will provide an interesting experience for students (Rio et al., 2023). Products in the form of AR learning media applications can help students understand atomic structure material better. Students can see the real form of atoms in 3D. This is supported by Supriadi et al., (2023) AR learning media is needed in chemistry learning to connect 3 levels of representation, namely macroscopic, symbolic, and submicroscopic.

This product is an application that can be used on an Android smartphone, so it is more practical because there is no need to bring props. Another advantage can use of AR with a network or without an internet network so that it is more efficient. AR learning media is classified as innovative because students can learn while playing by scanning markers so that students feel directly the sensation of learning in 3D in the real world, especially very suitable for use in science subjects. This is in line with Acesta & Nurmaylany, (2018) AR learning media is more interesting and effective in science subjects. On the other hand, the use of AR can also be used as a strategy, in motivating students to learn. In line with the use of AR can stimulate students' interest in science, and increase and interpret knowledge more deeply (Chen & Liu, 2020). AR technology has an impact on student learning independence. The use of AR increases the efficiency of students' independent work in learning (Nechypurenko et al., 2020). The use of AR has a positive influence especially on learner interest and engagement (Nurroniah et al., 2023). Augmented reality used in the learning process provides innovation, so that students become encouraged to learn, other contributions to the use of AR can enhance learning and improve skills (Rebello et al., 2024). Overall, students really like the learning media of atomic reality structure as seen from the enthusiasm and increased learning outcomes.

CONCLUSION

The results of this research in the form of an Android-based augmented reality atomic structure learning media application using the ADDIE model are deemed suitable for use. The development of this augmented reality atomic structure learning media has been validated, deemed highly practical, and effective in terms of effectiveness. The developers of the augmented reality (AR) application combine several applications including Unity, Blender, Vuforia Engine, and Canva. The use of AR in the atomic structure topic helps in understanding the material because learners can visualize atom models of Dalton, Thomson, Bohr, and Rutherford. AR technology is an innovative learning media, highly engaging, and can enhance learners' motivation to study, particularly in chemistry and science subjects. On the other hand, the practical and effective use of AR is through Android smartphones by scanning markers, making the learning atmosphere more enjoyable. The use of AR technology in the atomic structure topic has been proven to improve student learning outcomes. Future research could involve developing AR modules or e-books on other subjects.

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