

Development of Augmented Reality-Based Learning Multimedia on Volcanism to Enhance Visualization of Abstract Concepts in Senior High School

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ABSTRACT

Purpose of the study: This study aims to develop an Android-based Augmented Reality learning multimedia that integrates three-dimensional models of the internal structure of volcanoes for volcanism material in senior high school, and to test its feasibility as a learning medium.

Methodology: This research used a Research and Development approach with a modified Borg & Gall model consisting of eight stages. The product was developed using Unity 3D 2018.4.4f1 software, Vuforia SDK, and Blender 2.79b. Research subjects consisted of one media expert, two material experts, and 20 students of class X Social science 1 at State Senior High School 1 Ngaglik. Data were collected through observation and questionnaires using a Likert scale, then analyzed using descriptive quantitative analysis.

Main Findings: The media expert validation results obtained a score of 71 (Very Feasible), the combined score from two material experts was 146 (Very Feasible), and the student response test obtained a score of 1483 (Feasible). Black box testing showed that all features and navigation buttons functioned properly. The developed multimedia has six main menus with five sub-materials equipped with Augmented Reality pages to display 3D objects of volcano cross-sections, magma intrusion, magma extrusion, volcano morphology, and eruption types.

Novelty/Originality of this study: The novelty of this research lies in the comprehensive integration of three-dimensional models of the internal structure of volcanoes (magma intrusion cross-sections and magma chambers) in Android-based Augmented Reality multimedia that is portable, does not require special infrastructure such as Kinect sensors or projectors, making it more applicable for senior high school learning and filling the gap from previous studies that were still conceptual or required non-portable devices.

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1. INTRODUCTION

Learning geography, particularly volcanism, requires a high level of visualization to explain complex processes such as magma movement and volcano formation within the Earth's crust [1]. This material is abstract and cannot be directly observed, thus requiring media that can bridge theoretical concepts with students' concrete

understanding. However, based on initial observations at State Senior High School 1 Ngaglik, the volcanism learning process still relies on conventional media such as textbooks and worksheets [2]. This method is considered suboptimal because it only presents text and two-dimensional images that cannot fully represent the three-dimensional structure of volcanoes or the dynamics of volcanic processes. As a result, students experience difficulty understanding the material, learning interactions become passive, and the learning process is less engaging, potentially decreasing their motivation to learn [3].

The gap between the complexity of volcanism material and the limitations of conventional media is a major problem that requires innovative solutions [4]. Teachers are required to be able to create or select learning media that are appropriate to existing communication barriers, such as psychological and physical barriers experienced by students [5]. The unavailability of physical teaching aids or interactive multimedia in schools further complicates teachers' efforts to convey material comprehensively. In fact, volcanism material is rich in potential to be visualized through various formats such as images, videos, animations, and three-dimensional models [6]. Volcanism material is part of physical geography that requires contextual understanding because it contains many concepts to be learned. Therefore, learning media is needed that is not only informative but also interactive and able to display detailed object replicas to increase student understanding and learning interest.

Augmented Reality technology presents a potential solution with its ability to integrate two- or three-dimensional virtual objects into real-time environments. Previous research has proven the effectiveness of Augmented Reality in concretizing abstract concepts in various fields, such as the visualization of chemical molecular models by Silitonga and the development of basic electronics learning media by Burhanudin, the results of which were declared suitable for use [7]. These studies show that Augmented Reality is capable of creating interactive and immersive learning experiences, which can help students understand structures and processes that are difficult to explain with traditional media. This confirms that the use of Augmented Reality in learning can create a more interactive and effective learning atmosphere, and allows students to interact with three-dimensional virtual objects that appear in real environments. The application of Augmented Reality in learning about volcanism allows students to "present" volcano objects, see their cross-sections, and learn about the types of eruptions through 3D models and videos that appear above the marker.

Previous research, such as the development of vulk- Augmented Reality, has successfully visualized the process of volcanism and three types of volcanoes (strato, maar, shield) with very good validation results, but has not included detailed internal structures of volcanoes such as cross-sections of magma intrusions and magma chambers [8]. Meanwhile, other research, such as the development of Geo- Augmented Reality, focuses more on visualizing the earth's surface and contour lines through sandbox media with Kinect sensors, which require non-portable devices (projectors and special sensors), making it difficult to implement widely in schools with limited infrastructure [9]. In addition, various systematic literature studies such as this one only examine the impact of VR/ Augmented Reality conceptually on improving learning outcomes and higher-order thinking skills, without producing ready-to-use learning media products, and are limited to elementary education levels. Therefore, research is needed to develop multimedia learning for volcanism based on Augmented Reality on the Android platform that comprehensively integrates 3D models of the internal structure of volcanoes, is portable, and has been tested for its feasibility to meet the needs of geography learning at the high school level [10].

The novelty of this research lies in the development of Android-based Augmented Reality-based volcanism learning multimedia that comprehensively integrates three-dimensional models of the internal structure of volcanoes, such as cross-sections of magma intrusions and magma chambers, which have not been available in previous Augmented Reality media developments. In contrast to the developed Geo-Augmented Reality media that requires non-portable devices such as Kinect sensors and projectors, the developed media is portable, easily accessible, and does not require special infrastructure, making it more applicable for learning in high schools [11]. Thus, this research presents an innovative solution that not only fills the gaps in previous studies that are still conceptual, but also addresses the needs of geography learning at the high school level that has so far relied on conventional media.

The urgency of this research is based on the urgent need to address the low understanding of volcanism material by students due to the limitations of conventional media at State Senior High School 1 Ngaglik, which only rely on textbooks and two-dimensional images so that they are unable to represent complex processes such as magma movement and the internal structure of volcanoes [12]. The unavailability of physical teaching aids or interactive multimedia in schools further exacerbates the gap between the demands of abstract material and students' ability to visualize it, which has the potential to reduce their motivation and learning outcomes. Emphasizing that 3D object visualization can help students better understand volcanism material in geography learning because this material is a phenomenon that cannot be observed directly [13]. Therefore, the development of Augmented Reality-based learning multimedia on the Android platform is a necessity as an innovative solution that can provide an interactive learning experience, visualize the three-dimensional structure of volcanoes in detail, and address the challenges of infrastructure limitations with its portable and easily accessible nature.

This study aims to develop multimedia learning about volcanism based on Augmented Reality on the Android platform that specifically integrates 3D models of the internal structure of volcanoes, such as intrusion

cross-sections and morphology, and to test its feasibility in State Senior High School 1 Ngaglik. This approach offers a richer interactive learning experience than conventional media by allowing students to interact directly visually with abstract study objects [14]. The study concluded that the use of Virtual Reality/Augmented Reality in the learning process has a positive impact and is able to improve learning outcomes and higher-order thinking skills of students. The results of this study are expected to provide a real contribution in the form of proven innovative learning media that addresses the challenges of the limitations of geographic media while opening new opportunities for the use of Augmented Reality technology in the world of education.

2. RESEARCH METHOD

2.1. Research Design

This research uses a research and development approach that aims to produce a specific product and test its effectiveness [15]. The development model adapted in this research is the Borg & Gall procedure which has been modified into eight main stages due to time constraints and research conditions. These eight stages include: (1) research and data collection, (2) planning, (3) initial product development, (4) initial field trials, (5) operational product revision, (6) operational trials, (7) final product revision, and (8) dissemination and implementation. This procedure was chosen because the research and development approach is a link between theoretical and practical research, thus in accordance with the research objective of producing a learning multimedia product whose feasibility has been tested.

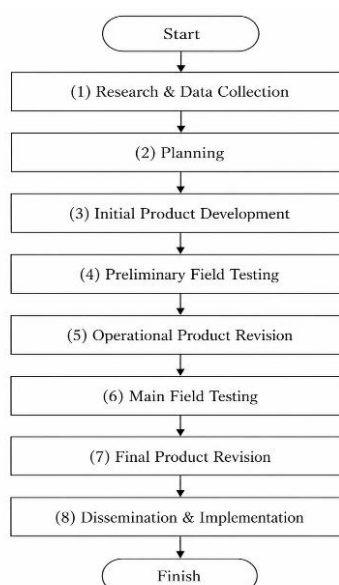


Figure 1. Development Stages

2.2. Research Subject and Objects

The subjects in this study were determined using a purposive sampling technique, involving relevant parties to assess the feasibility of the product [16]. The research subjects consisted of one media expert, namely a lecturer of the Informatics Engineering Education Study Program, Yogyakarta State University who is competent in the field of learning multimedia, two material experts, namely geography teachers at State Senior High School 1 Ngaglik, and 20 students of class X Social science 1 as respondents for the operational trial [17]. The object of this research is Augmented Reality-based learning multimedia for volcanism material developed for the Android platform [18]. The selection of research subjects and objects was based on the need to obtain comprehensive data regarding product quality from technical, material, and user experience aspects.

2.3. Data Collection Techniques

The data sources in this study were obtained through two data collection techniques, namely observation and questionnaires. Initial observations were conducted at State Senior High School 1 Ngaglik to identify learning problems and analyze product development needs [19]. Questionnaires were used to collect quantitative data Regarding product feasibility assessments from experts and student respondents. The research instrument was developed based on a grid that adapted David Squires' theory for student respondents and Romi Satria Wahono's theory for media experts and material experts [20]. The measurement scale used was a Likert Scale that had been modified into four answer choices (Strongly Agree, Agree, Disagree, Strongly Disagree) to avoid the tendency for neutral answers and obtain clearer data [21].

2.4. Data Analysis Technique

The data analysis technique used is quantitative descriptive analysis, namely by describing the data obtained from the questionnaire in the form of scores and converting them into feasibility values [22]. Data from media experts, material experts, and students were calculated for total scores, then averaged (especially for material experts) and converted into a table of predetermined feasibility criteria. The feasibility criteria consist of four categories, namely "Very Feasible", "Feasible", "Less Feasible", and "Not Feasible", which are determined based on the calculation of the ideal average (Mi) and the ideal standard deviation (SDi) [23]. Before being tested for feasibility, the product functionality was tested using the black box testing method to ensure all features and navigation buttons function properly.

3. RESULTS AND DISCUSSION

3.1. Product Development Results

This research produces a product in the form of Augmented Reality-based learning multimedia for volcanism material on the Android platform [24]. The product was developed using Unity 3D 2018.4.4f1 software with Vuforia Software Development Kit for Augmented Reality technology implementation, and Blender 2.79b for three-dimensional object creation. This multimedia has six main menus, namely the Standard of Competence and Basic Competence, Objectives, Learning, Test, Guide, and Profile menus [25]. In the Learning menu, there are five sub-materials, each equipped with an Augmented Reality page to display 3D objects or explanatory videos, such as volcano cross-sections, magma intrusions, magma extrusions, volcanic morphology, and eruption types [26]. Product functionality testing using the black box testing method shows that all available navigation buttons and features have functioned well as expected.

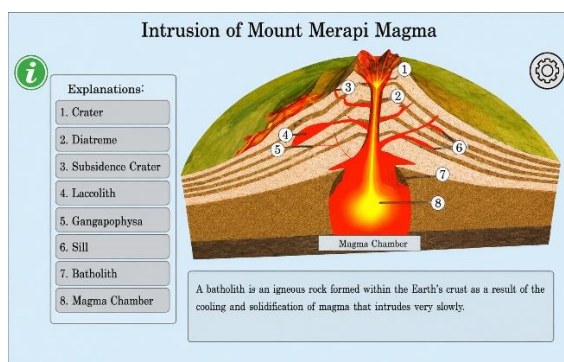


Figure 1. Intrusion Augmented Reality Page View

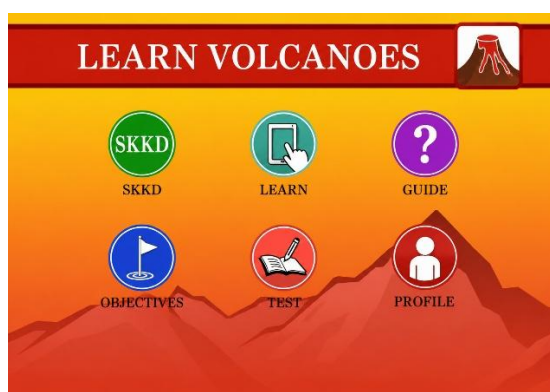


Figure 2. Main Menu Page

3.1. Feasibility Test Results by Media Experts and Material Experts

The product feasibility test was conducted through validation by one media expert and two material experts using a questionnaire instrument with a four-level Likert scale [27]. The validation by the media expert, conducted by Mr. Ponco Wali Pranoto, M.Pd., obtained a total score of 71. Based on the score conversion table, this score falls within the range of $68.25 < X \leq 84$, which falls into the "Very Feasible" category [28]. This assessment indicates that, from a software engineering and visual communication perspective, the developed media meets good quality criteria, such as ease of use, visual quality, and program reliability.

The validation by the material experts involved two geography teachers from State Senior High School 1 Ngaglik: Mr. Drs. Agus Sudibyo and Mrs. Kresensiana Ninik S, S.Pd. The first material expert gave a total score

of 80, while the second gave a total score of 66, resulting in a combined total score of 146. This total score falls within the range of $143 < X \leq 176$, which also falls into the "Very Feasible" category [29]. These results indicate that the volcanism material presented in multimedia is in accordance with the curriculum, has conceptual validity, adequate material depth, and systematic presentation so that it is suitable for use as teaching material.

3.2. User Response Test Results and Discussion

Operational trials were conducted on 20 students of class X State Senior High School 1 Ngaglik to determine user responses to learning multimedia [30]. The results of data collection showed the highest frequency in the "Agree" criteria with 319 choices, followed by the "Strongly Agree" criteria with 123 choices, the "Disagree" criteria with 16 choices, and the "Strongly Disagree" criteria with 2 choices. The total score obtained from all respondents was 1483, which based on the conversion table is in the range of $1150 < X \leq 1495$, so it is included in the "Feasible" category [31]. Although there were several students who gave a disagree assessment, overall this multimedia was considered suitable for use as a learning medium for volcanism.

Further discussion revealed that the developed product had several limitations, such as a 3D model that was still not smooth enough due to the developer's hardware limitations, and the material only covered the volcanism sub-topic and did not yet cover the entire Lithospheric Dynamics material. Suggestions for improvement from the validator, such as unclear video text and the need to package the markers in a pocket book, became the basis for revising the final product [32]. Overall, this Augmented Reality -based multimedia was proven to be able to increase interactivity and help visualize abstract concepts of volcanism, in line with previous research that stated that Augmented Reality is effective in concretizing learning materials.

3.3. Discussion

The development of Augmented Reality-based learning multimedia on volcanism material successfully provided a more interactive and innovative learning experience for students. The developed multimedia allows students to visualize abstract volcanism concepts such as magma intrusion, magma extrusion, volcanic morphology, and eruption types through three-dimensional objects and explanatory videos. This interactive visualization helps students understand learning material more easily compared to conventional learning methods that rely only on textbooks and verbal explanations. The implementation of Augmented Reality technology also increases student engagement and participation during the learning process. Therefore, the developed multimedia contributes positively to improving learning effectiveness and students' conceptual understanding.

From a technical perspective, the use of Unity 3D, Vuforia SDK, and Blender software proved effective in developing Android-based Augmented Reality multimedia. The black box testing results showed that all system navigation buttons and features functioned properly according to the expected requirements. The multimedia interface was designed to be simple and user-friendly, enabling students to operate the application independently without significant difficulties. In addition, the integration of three-dimensional models and learning videos enhanced the attractiveness and quality of the learning media. These findings indicate that the developed multimedia has good functionality and usability for classroom learning implementation.

The feasibility testing results conducted by media experts, material experts, and students further confirmed the quality of the developed product. The media expert validation obtained a score categorized as "Very Feasible," indicating that the multimedia fulfilled aspects of software engineering, interface design, and visual communication. Similarly, material experts stated that the content presented in the multimedia was appropriate to the curriculum, conceptually accurate, and systematically organized. Student responses also showed positive perceptions toward the multimedia, especially in terms of attractiveness, ease of use, and learning support. These findings support previous studies stating that Augmented Reality technology can improve student motivation, interaction, and higher-order thinking skills in the learning process.

Despite the positive results obtained, this study still has several limitations that should be considered for future improvement. The developed multimedia only covers volcanism material and has not yet included all topics within Lithospheric Dynamics learning materials. In addition, the quality of several three-dimensional models was still limited due to hardware constraints during the development process. Some validator suggestions, such as improving video text clarity and packaging the markers into a pocketbook format, also indicate that the product still requires further refinement. Therefore, future studies are recommended to expand the scope of learning materials, improve 3D object quality, integrate more interactive features, and develop applications compatible with broader platforms to optimize the effectiveness of Augmented Reality technology in education.

4. CONCLUSION

This research successfully developed an Augmented Reality-based learning multimedia application for volcanism material on the Android platform and tested its feasibility in the learning process at State Senior High School 1 Ngaglik. The validation results from media experts and material experts categorized the developed multimedia as "Very Feasible," while student responses categorized it as "Feasible" for learning activities. The

implementation of Augmented Reality technology proved effective in improving learning interactivity, supporting visualization of abstract concepts, and increasing student understanding of volcanism material. Therefore, the developed multimedia can be used as an innovative learning medium to support geography learning activities in senior high schools. Future research is recommended to expand the multimedia content to cover broader geography materials, improve the quality and detail of three-dimensional objects, integrate additional interactive features, and develop compatibility with various operating systems and mobile devices. In addition, further studies may evaluate the long-term impact of Augmented Reality-based learning media on student learning outcomes, motivation, and critical thinking skills to support the wider implementation of digital learning technologies in education.

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