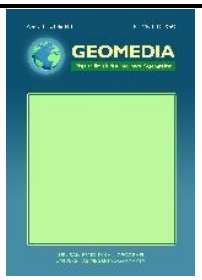

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G-Land 3D: Augmented Reality-Based Geography Learning Media Innovation to Support Improvement of Quality Education in the Sustainable Development Goals

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A B S T R A K

Pendidikan yang berkualitas merupakan fondasi utama dalam pembangunan sumber daya manusia, sebagaimana ditegaskan dalam Tujuan Pembangunan Berkelanjutan (SDG 4). Namun, pembelajaran geografi di tingkat sekolah menengah masih menghadapi kendala, khususnya dalam menyampaikan materi yang bersifat abstrak dan sulit divisualisasikan. Penelitian ini bertujuan untuk mengembangkan dan mengimplementasikan media pembelajaran G-Land 3D berbasis augmented reality, serta mengevaluasi efektivitasnya. Penelitian menggunakan metode Research and Development (R&D) dengan model ADDIE. Data dikumpulkan melalui angket, observasi, dan wawancara, lalu dianalisis secara kualitatif dan kuantitatif. Hasil menunjukkan bahwa G-Land 3D mampu meningkatkan pemahaman siswa terhadap konsep geografi secara signifikan. Temuan ini menunjukkan bahwa media pembelajaran berbasis teknologi G-Land 3D dapat memberikan kontribusi nyata dalam menciptakan pembelajaran yang lebih menarik, kontekstual, dan adaptif terhadap perkembangan teknologi, serta mendukung tercapainya SDG 4.

Keywords:
Learning Media
Additional Reality
G-Land 3D
Geography Education
Virtual Characters

A B S T R A C T

Quality education is the main foundation in human resource development, as affirmed in the Sustainable Development Goals (SDG 4). However, geography learning at the secondary school level still faces obstacles, especially in delivering material that is abstract and difficult to visualize. This research aims to develop and implement augmented reality-based G-Land 3D learning media, as well as evaluate its effectiveness. The research uses the Research and Development (R&D) method with the ADDIE model. Data was collected through questionnaires, observations, and interviews, and then analyzed qualitatively and quantitatively. The results show that G-Land 3D is able to significantly improve students' understanding of the concept of geography. These findings show that G-Land 3D technology-based learning media can make a real contribution in creating more interesting, contextual, and adaptive learning to technological developments, as well as supporting the achievement of SDG 4.

Introduction

Education is a basic right of every citizen that must be fulfilled by the state as stipulated in the Constitution of the Republic of Indonesia Article 31. In the preamble to the constitution, it is emphasized that Indonesia's national goal is to educate the nation's life. This statement emphasizes the importance of education as the main foundation in national development. In today's era of globalization and digital transformation, quality and inclusive education is not only a national priority but also part of a global commitment, as reflected in the fourth goal of the Sustainable Development Goals (SDG 4), namely "Quality Education". This goal emphasizes the need for equitable and equitable access to quality education as part of sustainable development.

Quality learning is an important indicator in achieving educational goals. Kustandi and Darmawan (2020) explained that learning is a deliberate process by teachers to help students learn based on their needs and interests. This definition underlines that the learning process must be designed with careful planning, student-centered, and supported by the teacher's active role as a facilitator. Therefore, teaching and learning activities require strategies that are not only cognitively effective but also able to develop the psychomotor and affective aspects of students. Optimal learning requires the active involvement of students through methods and media that are in accordance with the characteristics and challenges of the times.

Learning media is one of the important components in the educational process. According to Fidiyanti (2020), the use of appropriate instructional media can increase learning effectiveness, while inappropriate media can be an obstacle to achieving learning goals. In the context of rapid technological developments, learning media innovation is very important. Education in the digital era demands the integration of technology in teaching and learning activities in order to attract students' interest and be relevant to their daily lives. Therefore, the development of interactive and adaptive media is an important part of educational transformation.

The Industrial Revolution 4.0 era has brought major changes in various sectors, including education. Technologies such as the Internet of Things (IoT), artificial intelligence (AI), and augmented reality (AR) are increasingly being adopted in the world of education to create more engaging and meaningful learning experiences. Azuma (2008) explained that AR is a technology that combines virtual objects with the real world in real time. In the context of learning, AR allows students to understand abstract concepts through interactive three-dimensional visualization. The potential for the use of AR in education continues to grow, as projected by Maunder (2018) that the AR market in education will reach a value of 19.6 billion US dollars with an annual growth rate of 16.2% by 2023. This projection shows global enthusiasm for the application of immersive technology as a learning tool in the future.

The study of Al-Ansi et al. (2023) shows that the use of AR is able to bridge the gap between conventional learning in the classroom and the field learning experience. This technology provides an immersive immersive experience, allowing students to better explore complex concepts. In addition, AR supports personalized learning and fits each student's learning style (Phakamach et al., 2022; Sun et al., 2023; Childs et al., 2024).

However, while technology has great potential in supporting learning, challenges remain, especially in subjects such as geography. Geography as a science that studies geosphere phenomena through spatial and regional approaches often requires a deep understanding of spatial representations, such as maps and regional imagery. Otoluwa et al. (2020) mentioned that geography is considered a difficult subject because of the many abstract concepts that are

difficult to understand if they are only presented conventionally in the classroom. Meanwhile, geography learning will be more effective if it is associated with hands-on experience or simulations that are close to reality in the field.

Based on this background, this study aims to examine the development of augmented reality-based geography learning media to support the achievement of learning that is contextual, interesting, and adaptive to technological developments. This research focuses on the application of AR media in geography subjects in high schools that have implemented the Independent Curriculum, with the hope that it can be a solution to the challenges of conventional geography learning and contribute to the development of quality education in line with SDG 4.

Method

This research is research and development (R&D). The product under development is G-Land 3D Geography learning guidebook which is based on Augmented Reality and designed to help high school students improve their spatial knowledge. ADDIE (analysis, design, development, implementation, and evaluation) is a development model chosen by researchers because it is effective, dynamic, and helps program performance. This study employs the ADDIE development model established by Dick and Carey (1996), encompassing five distinct phases, as shown in Figure 1 below.

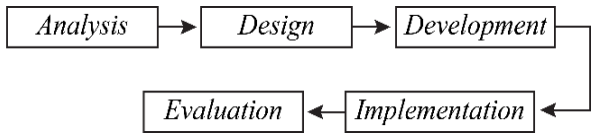

Figure 1. ADDIE Method as a Research Development Procedure

Each phase of the ADDIE model is elaborated in detail as described below

Analysis

At this stage, an analysis is carried out to assess the need for innovation in augmented reality (AR)-based learning media. This analysis includes the development of 3D model scenarios integrated with interactive books, as well as the evaluation of the requirements for their development.

Design

The process of creating a 3D model begins using Blender software. The 3D model developed is adapted to the learning material. Subsequently, the application program is developed as the next phase of the process. This stage starts with creating a background design and buttons for the application interface (UI). Next, a barcode that will be integrated with the Vuforia SDK is created. The Vuforia SDK package is incorporated into projects that are worked on using the Unity Engine. After that, some commands are structured using the C# programming language to set the application's functions. The built-in 3D model is integrated into the barcode layer. Once all the elements are set, the smartphone program is exported to the app in the form of an APK file. Subsequently, the development of the G-Land 3D book constitutes the next phase of the process. This process begins with compiling images, materials, and barcodes that are integrated into the pages of the book. The materials used are sourced from verified references, such as teaching materials from the Ministry of Education and Culture.

Development

At this stage, smartphone programs or Augmented Reality (AR)-based applications are integrated with the interactive physical books that have been created. Integration is done to ensure synchronization between 3D models, barcodes,

and materials in books. The end result of this stage is a learning medium that is ready to be tested and used.

Implementation

The implementation stage is aimed at teachers and students in secondary schools. Before the product is implemented, a pre-test is carried out to measure the knowledge of students and teachers in this learning media innovation. Furthermore, a trial of the 3D G-Land interactive learning guidebook based on Augmented Reality was carried out. Furthermore, a post-test was carried out to measure the success of this learning innovation.

Evaluation

The evaluation was carried out to analyze and improve the innovation shortcomings of the Augmented Reality-based G-Land 3D interactive learning book at the implementation stage.

Results and Discussion

Results

Development of G-Land 3D Learning Media

G-Land 3D learning media was developed using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) method. The following is a description of the development of G-Land 3 D.

Analysis Stages

The analysis stage in the ADDIE model is the first step that aims to identify the needs, problems, and conditions underlying the development of G-Land 3D learning media. This process is carried out through field observations, interviews with geography teachers, and interviews with students to find out their learning needs. Based on the results of observations at the research location, namely SMA N 4 Yogyakarta, it was found that teachers had difficulties in conveying abstract geographical material and required spatial understanding, such as the shape of the earth, tectonic processes, volcanism, and plate movement. Teachers tend to use conventional methods, such as lectures and print media in the form of maps or textbooks, which are often less effective in visualizing these concepts in a concrete way.

An interview with a geography teacher at SMA N 4 Yogyakarta obtained a statement that students had difficulty understanding geography material due to the limited interactive learning media. Research from Hadi (2020) reveals that materials such as topographic shapes, natural disaster processes, and changes in the earth's terrain are only presented theoretically without in-depth visual support. This leads to low interest in learning and students' limited understanding of the concepts of geography being taught. Interviews with grade X students of SMA N 4 Yogyakarta showed that most students found it difficult to understand geography learning, especially in materials that require visual and spatial understanding. AR-based media is considered to have great potential to help students visualize material in a more real and interactive way. Thus, this stage of analysis is an important basis in the development of G-Land 3D media. The focus of development is directed at geographical materials that require spatial visualization, such as the earth's terrain, tectonic processes, and the dynamics of the earth's layers. This stage also ensures that the media developed is in accordance with the needs of students and teachers, and is relevant to the objectives of geography learning at the high school level, especially for grade X students of SMA N 4 Yogyakarta

Design Stages

The design stage in the ADDIE model focuses on the initial design of G-Land 3D-based

learning media based on Augmented Reality (AR). This design aims to ensure that the learning media developed has a clear, effective structure, and is in accordance with the learning needs that have been identified at the analysis stage. The material chosen to be developed in the G-Land 3D learning media is a topic that is considered difficult for students to understand because of its abstract nature and requires spatial visualization. Therefore, the author focuses on the preparation of 3D G-Land material for this lithosphere dynamics that is usually taught to high school grade X students. The lithospheric dynamics material to be visualized includes the earth's layers, the distribution of the world's tectonic plates, the geological structure of faults, models of volcanoes and volcanic events, illustrations of earthquakes, and the types of rocks on earth. Each material is designed in the form of a 3D visual model that supports an exploration-based learning process. This media will be packaged in a modular manner so that it can be used flexibly according to the needs of teachers and students.

The user interface design and interactive elements of G-Land 3D learning media are made in the form of modules and applications. The visual design of modules and applications refers to the principles of simplicity, attractiveness, and user-friendliness. G-Land 3D modules are designed with the help of Microsoft Word software for scripts as well as Adobe Illustrator and Adobe InDesign software for module design displays. The G-Land 3D application is designed using software such as Blender for modeling and Unity 3D as an AR development platform. Figure 2 illustrates the user interface design of the G-Land 3D application.

Figure 2. G-Land 3D Application Interface Display

The main features of this learning medium include (1) marker scanning: This application will detect markers in the form of images or geographical symbols to display AR objects in 3D; (2) interactive rotation and zoom, students can rotate and zoom in on the 3D model to see the details of the material; (F3) animation of geographic processes, dynamic visualization of the Earth's layers, distribution of the world's plates, geological structures, and other lithospheric dynamic materials. Also, G-Land 3D learning media is designed to be applied in Project-Based Learning (PBL)-based learning scenarios. This strategy was chosen because it encourages students to actively learn through exploration, observation, and group discussions.

For output design, several initial design products are produced that are ready to be

developed in the next stage, such as 1) storyboards, flows and material presentation structures on G-Land 3D media; 2) application wireframe, G-Land application 3D initial interface display design; 3) 3D Conceptual Model: Sketch and design of three-dimensional models of geographic material in G-Land 3D module; and 4) learning implementation plans, in the form of teacher guidance in integrating AR media into geography learning in the classroom. This design stage ensures that G-Land 3D learning media is developed according to the needs of students and teachers, by incorporating engaging visual elements, interactive technology features, and innovative learning strategies. The results of this design will be a reference in the development stage to produce functional and effective learning media. Figures 3 and 4 below depict, respectively, the book cover design and the mobile application logo of G-Land 3D.

Figure 3. G-Land 3D Module Cover Design

Figure 4. G-Land App 3D Logo Design

Development Stages

The Development Stage at ADDIE focuses on the process of making initial tests of G-Land 3D learning media. 3D models of geographic objects such as landscapes (mountains, valleys, plains), movement of tectonic plates, and visualizations of volcanic eruptions developed with 3D modeling software. AR media is developed using Unity 3D as a platform and the Vuforia plugin to detect markers (trigger images). The process involves integrating the 3D model into Unity, the object will appear when the device (smartphone/tablet) scans the marker. G-Land 3D main features consist of (1) image scanning as a marker to display 3D objects; (2) interactivity through rotation, zoom and object exploration; (3) dynamic animation for geographical processes such as plate tectonic movement and volcanism. For G-Land 3D, the materials chosen are materials within the scope of lithosphere dynamics that are modularly packaged with a clear structure, such as the characteristics of the Earth's layer, tectonism and its impacts, volcanism and its impacts, seisms and impacts, and exogenous forces. The modules are also equipped with explanations and narrative instructions to guide students in exploring the content.

G-Land 3D learning media is curated through the validation stage to ensure content quality and technical feasibility. Some of these validations consist of material expert validation, media expert validation, linguist validation, and

limited trial with alpha test. Material experts assess very well the suitability of the material with the applicable curriculum, the potential of the material that supports the learning process, and the suitability of the material chosen for media development. Material experts assess with good criteria the suitability of the material to the needs of students, the potential of the material chosen for assessment, and the suitability of the material presented with the basic concepts and materials.

Media experts assessed very well the aspects of image clarity, elements of ease of understanding, suitability of media with the characteristics of high school students, and ease of access through (smartphone). Media experts assess aspects of the clarity of the writing, the attractiveness of the design and elements, the continuity of the flow of the display, and the accuracy of the use of color. However, media experts gave notes on the presentation of text that is too dominant, numbering that needs to be adjusted to standard rules, and the selection of wara so as not to seem contrasting. Linguists assess very well such as linguistic rules, suitability of the use of diction and terms with KBBI, and the use of language that is straightforward and easy to understand by students. Linguists also assess the criteria for good communicative language use, diction accuracy, ease of understanding language, and effective and standard sentence use.

After the validation process by several experts was completed, a limited trial (alpha test) was carried out on a small group of students in class X of SMA N 4 Yogyakarta (10 people) to assess the readability, functionality of the application, and the initial effectiveness of G-Land 3D. The results of the limited test show that the G-Land 3D app still has issues on certain devices. However, students can understand the instructions for using the app and the materials presented by G-Land 3D. Most students state that G-Land 3D helps them visualize geographic material that was previously difficult to understand.

Implementation Stages

The implementation stage in the ADDIE model is a step in the implementation of G-Land 3D learning media which is developed into real situations in the classroom. This stage aims to test the effectiveness of G-Land 3D learning media in helping students understand geography material and observe how the media is integrated in the learning process. The application of G-Land 3D learning media was carried out in class X-E1 of SMA N 4 Yogyakarta. Before the implementation was carried out, preparatory steps had been taken to ensure the smooth learning process, which consisted of (1) coordination with the geography teacher concerned, geography teachers were given short training on the use of G-Land 3D media, how to run the application, scan markers, and explain the material with 3D visualization; (2) Infrastructure preparation, students are asked to prepare supporting devices such as smartphones/tablets that have been downloaded from the G-Land 3D application. Then, make sure the internet network and G-Land 3D markers in printed or digital form have been prepared; (3) the preparation of a lesson plan (Learning Implementation Plan), which is designed using a project-based learning (PBL) approach so that students learn actively through media exploration, discussion, and problem-solving related to geography materials. ; (4) make pre-test and post test questions to get students' understanding of the material before using G-Land 3D media which will be tested with pre-test and after using G-Land 3D media, students' understanding is tested again using post-test.

The implementation of G-Land 3D learning media was carried out on 31 students in class X-E1 of SMA N 4 Yogyakarta. The G-Land 3D test was performed 1 time for 3 JP (135 minutes). The implementation of learning consists of an introduction, the implementation of pre-tests, core activities of geography learning using G-Land 3D media, the implementation of post-tests, and closing. Data were collected during

implementation to evaluate the effectiveness of G-Land 3D media in geography learning in class X-E1. The data collection method includes (1) observation, to observe student involvement in learning. Teachers record students' exploration activities, participation in discussions, and use of G-Land 3D media; (2) student interviews, conducted to students to find out their perception of G-Land 3D media, especially related to the ease of use, attractiveness, and contribution of media to the understanding of the material; (3) learning outcome tests, conducted pre-test before learning and post-test after study to measure the improvement of students' understanding of geography material.

Observations show that students in class X-E1 are very enthusiastic and active in using G-Land 3D media. All students were seen to be involved in exploring the material independently and discussing with their groups. G-Land 3D media encourages students to focus and participate in learning. The results of the interviews also showed that students felt that G-Land 3D media helped them understand abstract geography material, especially lithospheric dynamics material. Students stated that 3D visualization makes the material more interesting and easy to understand than conventional learning methods. From the analysis of student learning outcomes, it shows a significant increase in understanding of the material taught. The average pretest score of students in class X-E1 is 39, while the post-test score shows an increase to 74.8, this indicates an increase of 35 points. G-Land 3D media has proven to be effective in improving students' understanding of geography concept material. Figures 5 through 8 below illustrate the sequence of activities conducted during the implementation of the G-Land 3D application at SMA N 4 Yogyakarta

Figure 5. Implementation of Pre Test and Post Test in Class X-E1 SMA N 4 Yogyakarta

Figure 6. Implementation of Learning with G-Land 3D Media in class X-E1

Figure 7. Students Utilize G-Land 3D Augmented Reality Features

Figure 8. Giving Appreciation to Students with the Highest Post-Test Scores

Evaluation Stages

This stage is aimed at assessing the effectiveness, efficiency, and quality of G-Land 3D learning media that has been implemented. Formative and summative evaluations were carried out to provide a comprehensive overview of the advantages, weaknesses, and impacts of G-Land 3D media and improve the quality of geography learning (Nuriyanto et al, 2022). Formative evaluations are carried out during the process of developing and deploying AR media, including validation from experts and limited trials. Material experts assess it very well in relation to the potential of the material in supporting the learning process, and the suitability of the material chosen for media development. In addition, examining the suitability of the material with the needs of students, the effectiveness of the material when delivered in lessons. The potential of the material selected for assessment, as well as the suitability of the material presented with the concepts and basic materials that are already good.

Media experts assessed very well the aspects of image clarity, elements of ease of understanding, suitability of media with the characteristics of high school students, and ease of access via mobile phones/PCs. In addition, it assesses aspects of writing clarity, design and element appeal, display flow collapse, and accuracy of color usage. However, media experts provided notes related to G-Land 3D media about the presentation of text that is too dominant, the use of numbering that still needs to be adjusted to standard rules, and the selection of color that lacks contrast. Linguists assessed very well several aspects of G-Land 3D language such as linguistic rules, the suitability of the use of diction and terms with KBBI, the use of language that is straightforward and easy for students to understand, and the use of sentences that represent the information conveyed. Good criteria are also found in the aspects of the use of communicative language, accuracy of diction, ease of understanding the language, and effective use of standard sentences. The results of the limited test show that the G-Land 3D app still has issues on certain devices. However, students can understand the instructions for using the app and the materials presented by G-Land 3D. Most students state that G-Land 3D helps them visualize geographic material that was previously difficult to understand.

Summative evaluation was carried out after the application of G-Land 3D media in the classroom by involving the analysis of data on student learning outcomes, student responses, and teacher responses. This evaluation aims to measure the effectiveness of G-Land 3D media in supporting geography learning. Evaluation of improving student learning outcomes is carried out through Pre-test and post test. The average pretest score of students in class X-E1 is 34, which indicates that students' initial understanding of lithospheric dynamics prior to the use of G-Land 3D media is still low. Value post-test The average number of students increased to 74.8, showing a significant increase of 35 points, after students learned using G-Land 3D media.

The students' response to the use of G-Land 3D media is known from the results of the interview. The results of the study showed that students of class X-E1 of SMA N 4 Yogyakarta felt that G-Land 3D media helped them understand geography material more easily, clearly, and increased motivation to learn geography. The students' comments reflect the high enthusiasm for G-Land 3D media because it presents an

interactive, real and modern learning experience. The Geography teacher of SMA N 4 Yogyakarta gave a positive response to the use of G-Land 3D media in learning. Helps explain abstract concepts concretely and visually. Learning becomes more active, collaborative, and engaging as students explore the material independently. But, the teacher also provided input related to technical constraints, such as the limited number of devices owned by students and dependence on the internet network, so that backup solutions such as borrowing devices or offline use were needed.

Implementation of G-Land 3D Learning Media at SMA N 4 Yogyakarta

The implementation of G-Land 3D learning media was carried out in class X-E1 of SMA N 4 Yogyakarta. Class X-E1 was chosen as the subject because of the recommendation of the geography teacher of SMA N 4 Yogyakarta that students in class X-E1 have a proportionate composition of students in terms of student ability and understanding. The material contained in G-Land 3D is lithospheric dynamics material that is taught to students in class X phase F at the high school level. The effectiveness of G-Land 3D media was measured by using a test analysis of student learning outcomes, namely with pre-test and post-test instruments. This instrument is used to see differences in students' understanding and knowledge before and after applying G-Land 3D learning media. The results of the pre test showed that the average score of the students was 34 with the highest score of 75 and the lowest score was 5. The results changed drastically after students received learning treatment with G-Land 3D media through a post test with the same questions. The results of the post test showed an average score of 74.8, with the highest score of 100 and the lowest score of 25. To see the difference in the results of pre-test and post test students in class X-E1, a different test was carried out using a paired sample t-test. Before the paired sample t-test was carried out, normality and homogeneity tests were carried out as a prerequisite (Septiyowati & Prasetyo, 2021). Figures 9 and 10 present the outcomes of the normality and homogeneity tests conducted on students' pretest and posttest scores using SPSS

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Kelas	Statistic	df	Sig.	Statistic	df	Sig.
Nilai Ujian	Pre Test	.127	31	.200*	.980	31	.822
	Post Test	.135	31	.157	.927	31	.037

Figure 9. Pretest and Posttest Score Normality Test Results with SPSS Software.

		Levene Statistic	df1	df2	Sig.
Nilai Ujian	Based on Mean	.606	1	60	.439
	Based on Median	.592	1	60	.445
	Based on Median and with adjusted df	.592	1	56.711	.445
	Based on trimmed mean	.640	1	60	.427

Figure 10. Homogeneity Test Results of Pre-Test and Post-Test Scores with SPSS Software.

Based on the normality test of the data using the Kolmogorov-Sminorv and Shapiro-Wilk tests, the significance assessment (Sig.)> 0.05 which shows that the data of pre-test and post-test scores of students are distributed normally. Meanwhile, the results of the data homogeneity test also showed a significance value (Sig.)> 0.05 on all parameters, which means that the data were homogeneous pre test and post test values. This is because the prerequisites have been met. Therefore, different tests can be performed to see the significance level of the difference in students' pre-test and post-test scores using a pair sample t-test. Figure 11 displays the results of the independent t-test conducted on students' pretest and posttest scores with the assistance of SPSS software.

Paired Samples Test

		Paired ... 95% Confidence Interval of the ...			
		Upper	t	df	Sig. (2-tailed)
Pair 1	Pre Test - Post Test	-28.968	-11.121	30	.000

Figure 11. The results of the test are Paired Samples of Pretest and Posttest scores of students.

Different test results using the paired sample t-test showed a significance value (sig.(2-tailed)))<0.05 which showed a significant difference between the pre-test and post-test values. Pre-test and post test scores that showed significant differences showed differences in students' abilities and understanding before and after using G-Land 3D media in lithospheric dynamics learning. The difference is positive because there is an increase in students' understanding and ability to understand the concepts of the material taught with G-Land 3D media.

Advantages and Disadvantages of G-Land 3D Media

As a product of research and development in the education sector, G-Land 3D learning media has several advantages, including (1). interactive 3D visualization helps students understand complex geography material; (2). media that attracts students' interest in learning and increases active involvement in learning; (3). Easy-to-use and user-friendly interface appearance. The use of mobile application-based AR in G-Land 3D is one of the innovations and contributions to improving the quality of learning media, especially in the field of geography. Improving the quality of learning media will also improve the quality of learning in the classroom so that it is expected to produce progressive student learning achievements.

G-Land 3D products also have several drawbacks such as the large size of the mobile application so that it requires large smartphone storage and adequate specifications. In addition, the mobile application from G-Land 3D is only available on the Playstore so it cannot be accessed by smartphone users other than Android and requires a smooth and stable internet connection. Another drawback of G-Land 3D is that this medium is still limited to making lithospheric materials in geography subjects. This makes this media unable to be used for learning on other geography materials. Thus, other R&D research needs to be carried out to develop similar learning media that are more flexible to be used throughout the learning of geography materials in schools.

Discussion

Quality education is one of the goals of the Sustainable Development Goals (SDGs) point 4. The meaning of this goal is to ensure quality education that is inclusive, equitable, and promotes lifelong learning opportunities for all groups. Transformation in the education sector, especially in building education that is adaptive to the development of the times, is one of the efforts to create a quality education climate. Priantini et al. (2022) stated that the implementation of the independent curriculum as a national curriculum that is claimed to be adaptive in today's era is a manifestation of quality education in Indonesia.

Quality education is obtained from quality learning. Quality learning is supported by educators and learning tools that are also quality, one of which is in learning media. The rise of the use of AR in the current era can be used as a medium that improves the quality of learning in the classroom. Augmented Reality (AR)-based learning media plays an important role in supporting the achievement of this goal in creating innovative, inclusive, and effective learning in the era of digital technology (Thahir & Kamaruddin, 2021).

This study develops an AR-based learning media that is specifically for geography learning in the classroom called G-Land 3 D. The use of Augmented Reality (AR) media such as G-Land 3D in geography learning allows students to understand abstract and complex concepts through interactive visualizations in 3D. For example, the processes of tectonism and volcanism are in the form of 3D animations so that students can see firsthand how plate tectonics or volcanic eruptions move. The earth's surface, such as mountains, valleys, and plains, is displayed in the form of real objects that can be rotated, magnified, and studied from various angles.

Visualization makes learning more contextual and real, helping students understand the material faster and deeper. This is in accordance with the principle of quality education that emphasizes understanding concepts, not just memorization.

The application of AR technology such as G-Land 3D allows for more inclusive learning because the media can be used by several groups of students, including those with visual or kinesthetic learning styles, thus supporting equitable education. In the use of learning media, it is important to pay attention to the different learning styles of students and utilize different types of media to support the learning process. Abstract geography material can be understood by students from a variety of social, economic, or geographical backgrounds, including students in remote areas who have limited access to laboratories or physical learning media. Sari et al. (2023) revealed that AR technology can be used flexibly, both in the classroom and at home, through simple devices such as smartphones/tablets. Likewise, the G-Land 3D product is AR-based and is already available as a smartphone mobile application so that it is more flexible for students to access.

G-Land 3D has been empirically tested based on the results of tests conducted at SMA N 4 Yogyakarta, precisely in classes X-E1 when learning geography when the lithosphere dynamics material. Students' understanding of the material has increased from before the use of the media in the classroom. This is evidenced by the increase in the students' post test scores and the independent sample t-test statistical test with a significance value of less than 0.5. It also shows that there is a significant difference in the learning outcomes of students in class X-E1 from before and after using G-Land 3D with a positive trend.

AR media like G-Land 3D provides an interactive, engaging, and fun learning experience. Dynamic visualization encourages students to be more active in exploring the material, asking questions, and discussing. AR media creates student-centered learning and fosters 21st-century skills such as creativity, collaboration, and critical thinking. In addition, AR-based Learning media such as G-Land 3D can help address the gap in educational quality between urban and rural schools. Altmeyer et al. (2020) in their research revealed that AR can be used as a medium to create virtual laboratories that can provide reality-based learning to students in the classroom. Schools with limited physical facilities and infrastructure such as rural schools can utilize AR technology for virtual labs for classroom learning including geography subjects

AR media like G-Land 3D is not only limited to classroom use, but also encourages students to continue learning independently outside of school hours. Through this, students can learn anytime and anywhere, in line with the principles of lifelong learning carried out in SDGs 4 goals. This implementation also teaches students to get used to using technology as a means of learning. The regular use of reality-based geography learning media such as G-Land 3D contributes to the achievement of SDGs 4 goals by improving the quality of learning through innovative and interactive technologies, creating equitable access to education with inclusive and flexible media, motivating students to actively participate in engaging and meaningful learning, reducing educational gaps and providing alternative school solutions for limited resources (Tasrif et al., 2020). Thus, AR-based learning media is not only a technological innovation, but a real solution in creating quality education that is accessible to all parties. This is in line with global efforts to ensure that every child, without exception, has fair and relevant learning opportunities and supports future development.

This research still has some limitations that it is hoped can be improved by other studies in the future. The results of the evaluation showed that the G-Land 3D learning media had several shortcomings both from the media itself and when its implementation in schools. Some of the disadvantages of G-Land 3D in terms of media are the need for large storage, adequate smartphone devices, not yet available to other android users, stable and smooth internet connections, and still

limited development for lithospheric material in geography subjects. Meanwhile, the disadvantage of G-Land 3D in terms of implementation is that the students have not been able to operate this media independently due to complex media technical tools. It is hoped that in the future, research can be carried out on the development of similar learning media with more adequate specifications and can be used for all materials in all subjects in schools.

Conclusion

The implementation of G-Land 3D carried out at SMA N 4 Yogyakarta produced positive scores by making it easier for students to understand the concept of geography which has been known to be abstract and needs to be visualized interestingly. Different test results show that there is a significant difference between students' pre-test and post-test scores, which means that there is a difference in students' understanding and ability between before and after learning geography using G-Land 3D. The application of G-Land 3D in learning also supports quality education efforts and participates in realizing the 4th point of the sustainable development goals (SDGs). namely ensuring quality and inclusive education, and supporting lifelong learning opportunities for all.

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