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Development of Augmented Reality (AR)–Based Interactive Geography Learning Media to Improve Students' Learning Outcomes

Sefia Apriyani [1], Rahma Kurnia Sri Utami [1], Dian Utami [1]
[1]Department of Geography Education, Faculty of Teaching, Training and Education, University of Lampung, Bandar Lampung City, Indonesia
*Email: sefiaapriyani00@gmail.com

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Correspondent Author:
Sefia Apriyani,
Department of Geography Education, Faculty of Teaching, Training and Education, University of Lampung, Bandar Lampung City, Indonesia
E-mail :
sefiaapriyani00@gmail.com

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ABSTRACT

In the era of rapidly developing technology, the need for innovation in education is becoming increasingly important, especially in introducing abstract and complex concepts, such as those found in geography learning. However, the limitations of conventional learning media sometimes make it difficult for students to understand abstract processes such as the hydrological cycle. This study aims to develop interactive geography learning media based on Augmented Reality (AR) on the hydrological cycle to improve the learning outcomes of grade X students of SMA Negeri 1 Labuhan Ratu. The research method used is Research and Development (R&D) with the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). Validation of learning media was carried out by several experts, with the results of media expert validation of 82,5% (good/feasible), material experts 78,2% (good/feasible), language experts 84,6% (good/feasible), and practitioners 95.5% (very good/feasible). In addition, user validation (students) showed a result of 91,5%, which is also in the very good qualification. Testing the effectiveness of this media was carried out using the pretest and posttest methods, and analyzed using the paired sample t-test statistical test. Based on the results of the analysis, it was obtained that the Sig. (2-tailed) <α (0.05), which indicates that H0 is rejected and H1 is accepted. Thus, it can be concluded that there is a significant increase in learning outcomes in students after using this AR-based learning media. This learning media is not only considered feasible by experts and students but has also proven effective in improving understanding of the concept of the hydrological cycle. These results indicate that AR media can be an innovative alternative in interactive and in-depth geography learning.

INTRODUCTION

Education is the primary foundation for national development because it plays a role in producing quality, knowledgeable, and character-based human resources. Law Number 20 of 2003 concerning the National Education System affirms that education is a conscious and planned effort to create a learning environment that allows students to actively develop their potential. In the context of 21st-century learning, teachers are required to provide a learning process that is not only teacher-centered but also student-centered to create meaningful, active, and contextual learning (Hardianti et al., 2020; Siskawati, 2016).

One of the challenges in today's education world is how to provide learning that can accommodate various learning styles of students. Conventional methods such as lectures or textbooks tend to make students passive, as information is received in one direction without in-depth interaction. The use of two-dimensional learning media (images and text) leads to limited visualization of complex abstract concepts (Andari, 2019). This condition results in decreased student interest in learning and less than optimal learning outcomes (Wardani et al., 2019). Therefore, innovative, interactive, and contextual learning media are needed to bridge the gap between theoretical concepts and the realities faced by students (Abdaul, 2020). Geography is a subject that requires students to understand natural and social phenomena spatially. Many concepts in geography are abstract, such as the structure of the earth, atmospheric dynamics, and the hydrological cycle, which require visualization for easy understanding. One important topic in geography learning is the hydrological cycle, the process by which water circulates on Earth through the stages of evaporation, condensation, precipitation, and infiltration (Pratomo, 2020). These processes are difficult to visualize simply through still images in textbooks, so students often struggle to understand the interrelationships between them.

The development of digital technology in education has opened up significant opportunities to address these issues. One promising innovation is Augmented Reality (AR). According to Kamelia in Ramadani et al. (2020), Augmented Reality is a technology that combines three-dimensional (3D) virtual objects into a real-world environment in real time. This technology allows students to interact with visual objects that resemble their original forms, allowing abstract concepts to be visualized in real time. AR provides a more immersive, interactive, and motivating learning experience because it incorporates elements of play (gamification) and high levels of visual exploration (Aggarwal & Singhal, 2019; Carolina, 2022).

Various previous studies have demonstrated the effectiveness of using AR in learning. Ramadhani et al. (2020) developed an AR-based chemistry module and found significant improvements in high school students' learning outcomes. Alfitriani et al. (2021) reported that using AR media to introduce landforms resulted in an 89.71% student interest rate, indicating that this media is highly effective in increasing learning motivation. Research by Oktaviani et al. (2022) also confirmed that AR media assisted by Assemblr Edu met the criteria for validity and feasibility, with a validity percentage above 90%. Although research on AR is increasing, the application of this technology in geography learning in high schools remains limited. Based on observations and interviews with geography teachers at SMA Negeri 1 Labuhan Ratu, it was found that learning still uses conventional methods with media such as textbooks and PowerPoint. Teachers have not yet used Augmented Reality-based media due to limited capabilities in technology development and a lack of supporting digital facilities. As a result, students show low learning interest and have difficulty understanding the concept of the hydrological cycle comprehensively.

This situation indicates a gap between the potential of available learning technology and the learning practices carried out in schools. Therefore, this research was conducted to develop interactive geography learning media based on Augmented Reality (AR) integrated through the Google Sites and Assemblr Studio platforms. This media is designed to enable students to learn the hydrological cycle process visually, interactively, and contextually by directly observing 3D animations through digital devices such as mobile phones or tablets. Theoretically, the development of this media is based on several main theories. First, the Cognitive Theory of Multimedia Learning by Mayer (2009), which emphasizes that learning is more effective when information is presented through a combination of verbal and visual channels. Second, the Constructivism Theory by Piaget (1973), which states that students actively construct their knowledge through direct learning experiences. Third, the Learning Motivation Theory by McClelland (1987), which explains that learning based on real-life experiences can increase student motivation and academic achievement.

In addition, this study adopted a Research and Development (R&D) approach with the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model as proposed by Reiser & Mollenda in Rangkuti (2016). The ADDIE model was chosen because it is able to provide systematic stages in developing educational products, starting from needs analysis to evaluation of media effectiveness.

Thus, this research has two main objectives, namely: Developing interactive geography learning media based on Augmented Reality (AR) using Google Sites and Assemblr Studio on the hydrological cycle material for class X students of SMA Negeri 1 Labuhan Ratu. To determine the feasibility and effectiveness of the media in improving student learning outcomes. This research is expected to provide theoretical and practical benefits. Theoretically, the research results enrich the study of the development of technology-based learning media, particularly in geography learning. Practically, the developed media can be an alternative for teachers in implementing interactive and innovative learning, increase student learning motivation, and serve as a model for the application of digital technology in secondary schools. Thus, the development of Augmented Reality-based learning media can be a strategic step towards 21st-century education that is adaptive to technological advances and student needs.

METHOD

This study uses the Research and Development (R&D) method, which aims to produce new products in the field of education and test the level of feasibility and effectiveness of these products in improving the quality of learning. According to Sugiyono (2017), the R&D method is a systematic research process to create, refine, and test products so that they are valid, practical, and effective for use in learning contexts. In this study, the product developed is an interactive geography learning media based on Augmented Reality (AR) on the hydrological cycle material for class X students of SMA Negeri 1 Labuhan Ratu.

The development model used in this study refers to the ADDIE model, which consists of five main stages: Analysis, Design, Development, Implementation, and Evaluation (Hidayat & Nizar, 2021). This model was chosen because it is considered systematic and relevant for the process of developing technology-based learning media. The first stage, analysis, was conducted to identify student and teacher needs for learning media and analyze problems that arise in the geography learning process. The analysis results showed that the learning process at SMA Negeri 1 Labuhan Ratu is still conventional, teacher-centered, and does not yet use digital media based on Augmented Reality. This condition makes it difficult for students to understand abstract material such as the hydrological cycle. This stage also involved field observations, interviews with geography teachers, and gathering information on the characteristics of grade 10 students.

The next stage is design. At this stage, the initial design of the learning media to be developed is carried out. The design process includes creating a storyboard, designing the interface, developing a navigation structure, and planning the content to be presented through Google Sites and Assemblr Studio. The media design is tailored to the needs of geography learning and includes elements of text, images, videos, animations, and 3D models to visually explain the hydrological cycle process. In addition, during the design stage, research instruments are also prepared in the form of expert validation sheets, student response questionnaires, and learning outcome tests to measure the effectiveness of the developed media.

The third stage, development, is the implementation stage of the previously created design. At this stage, the learning media is developed by integrating AR-based three-dimensional objects using Assemblr Studio, which is then connected to the Google Sites platform. The media is designed to be accessible via smartphone by scanning a QR code that is directly connected to the learning page. After the media is developed, a validation process is carried out by experts, including media experts, material experts, linguists, and education practitioners (geography teachers). Each validator assesses the media's appearance, content, language, and usability using a Likert scale, and provides suggestions for product improvements. The validation results indicate that this AR-based learning media meets the criteria of "good" to "very good" in all assessment aspects.

The fourth stage is implementation. At this stage, the learning media that has been declared suitable by experts is directly applied in teaching and learning activities in class X SMA Negeri 1 Labuhan Ratu. The implementation was carried out in the odd semester of the 2024/2025 academic year, involving 35 students. The learning process began with a pretest to determine students' initial abilities in the

hydrological cycle material, continued with learning using AR media, and ended with a final test (posttest) to measure the improvement in learning outcomes after the treatment. During the implementation, researchers also conducted observations and administered questionnaires to students to assess their responses, interest, and ease of use of the developed media.

The final stage in the ADDIE model is evaluation. Evaluation is conducted both formatively and summatively. Formative evaluation is conducted at each stage of development to assess product weaknesses and make continuous improvements. Meanwhile, summative evaluation is conducted after media implementation to assess the level of feasibility and overall effectiveness. The evaluation results are used to determine whether the developed learning media meets the criteria of validity, practicality, and effectiveness, and can be widely used in other schools. This research was conducted at SMA Negeri 1 Labuhan Ratu, East Lampung Regency, with the implementation time in the odd semester of the 2024/2025 academic year. The research subjects were 36 students of class X.1, while the research object was interactive geography learning media based on Augmented Reality (AR) on the hydrological cycle.

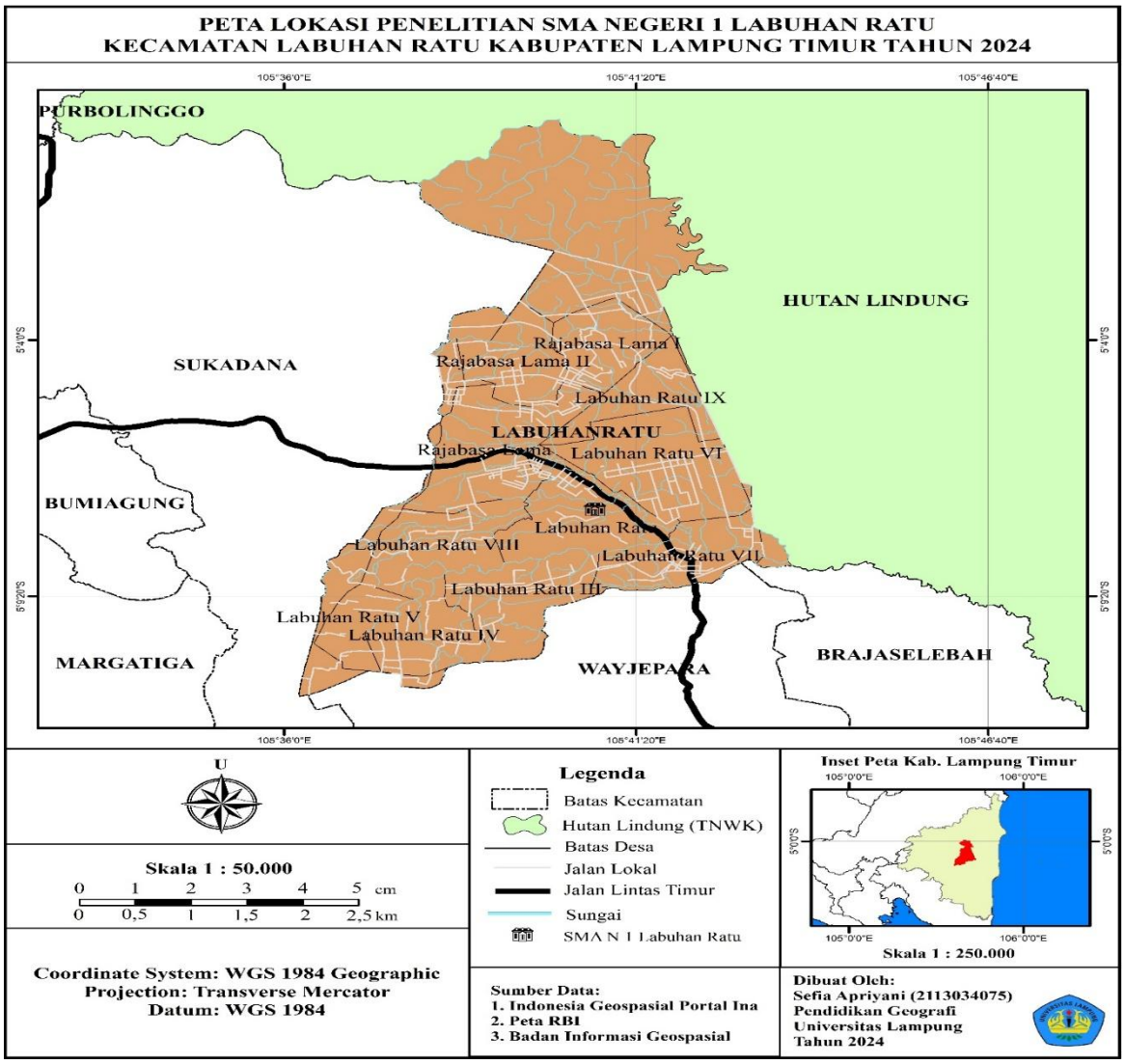

Figure 1. Research Location Map

The data collection techniques in this study consisted of several methods, namely observation, interviews, expert validation, student response questionnaires, and learning outcome tests. Observations and interviews were used to identify learning needs and constraints in schools. Expert validation was conducted to assess the feasibility of the developed media from various aspects. The questionnaire was used to determine students' responses to the media, while the learning outcome test

was used to measure the increase in students' understanding of the material after using AR media. The learning outcome test consisted of 20 multiple-choice questions that had been tested for validity, reliability, discrimination power, and difficulty level. The data obtained were analyzed quantitatively descriptively and inferentially. Descriptive analysis was used to describe the results of expert validation and students' responses to the media, while inferential analysis was used to test the effectiveness of the media through a Paired Sample T-Test statistical test. The test was conducted with the help of SPSS software using a significance level of 0.05. If the Sig. (2-tailed) value <0.05, there is a significant difference between the pretest and posttest results, which indicates that the use of AR media has a positive effect on improving student learning outcomes.

Throughout the research process, ethical research principles were maintained by requesting official permission from the school, involving teachers as research partners, and ensuring that student participation was voluntary and confidential. All data obtained was used solely for academic purposes and the development of learning media. Based on all these stages, this research method is expected to produce a valid, practical, and effective Augmented Reality (AR)-based geography learning media product for use in the learning process. The systematic approach of the ADDIE model allows for thorough testing of each development stage, so that the resulting media is able to support improved learning outcomes, strengthen student motivation, and provide a more interactive and meaningful learning experience in accordance with the demands of 21st-century education.

RESULTS AND DISCUSSION

This research resulted in an interactive geography learning media based on Augmented Reality (AR) developed using two main platforms, namely Google Sites as the main platform for presenting the material, and Assemblr Studio to display three-dimensional (3D) objects that can be projected in real time via mobile devices. This media was developed to visualize the hydrological cycle process which includes the stages of evaporation, condensation, precipitation, and infiltration interactively, so that students can understand the flow and interrelationships between processes more easily.

This learning media consists of several main sections, namely the opening page, main menu, learning materials, AR simulation, evaluation, interactive games, and developer profiles. The interface is designed to be simple, attractive, and easily accessible via both computers and mobile devices. The use of barcodes and interactive links allows students to quickly access the media without the need for additional installation. In the AR simulation section, students can point the device's camera at a specific marker or image which then displays a three-dimensional animation of the hydrological cycle process. This provides an immersive and contextual learning experience, in accordance with the principles of visual-spatial-based learning in the Cognitive Multimedia Learning theory (Mayer, 2009). Before being used in learning, the developed media was first validated by four experts: a media expert, a material expert, a linguist, and a practitioner (geography teacher). Based on the validation results, an average feasibility score of 88% was obtained from the media expert, 98% from the material expert, 84.6% from the linguist, and 95% from the education practitioner. This value is included in the very appropriate category and shows that the Augmented Reality-based learning media developed has met quality standards in terms of content, appearance, language, and usefulness in learning.

After the validation and revision process, a limited trial was conducted in class X of SMA Negeri 1 Labuhan Ratu with 35 participants. The trial was conducted to measure the effectiveness of the media in improving student learning outcomes on the hydrological cycle material. Data were collected through learning outcome tests (pretest and posttest) and student response questionnaires. The results of the Paired Sample T-Test showed a significance value (Sig. 2-tailed) of 0.000 <0.05, which means there is a significant difference between the pretest and posttest scores. Thus, it can be concluded that the use of AR-based learning media significantly improves student learning outcomes.

Table 1. Results of *the T-Test* on Student Learning Outcomes

Pired Samples Test							
		Paired Differences					
		Mean	*Standard Deviation*	*Std. Error Mean*	*t*	*df*	*Sig. (2-tailed)*
Pair 1	*Pretest-Posttest*	-18,750	7,962	1,327	-14,130	35	.000

Source : Research Results, 2024 .

This improvement in learning outcomes is also reflected in the average student test scores. Before using AR-based learning media, students' average pretest score was in the moderate category, with an achievement of 67.22. After learning using AR media, the average posttest score increased to 86.94. This indicates a 19.72-point increase in learning outcomes, proving that the developed media effectively helps students understand the hydrological cycle material in a more in-depth and enjoyable way.

In addition to improving learning outcomes, this learning media also received a positive response from students. Based on the results of the questionnaire, 91.5% of students stated that this learning media was interesting, easy to use, and helped them understand abstract material. Students felt more enthusiastic while learning because they could directly observe three-dimensional simulations of hydrological processes. This aligns with McClelland's (1987) Learning Motivation theory, which states that challenging and enjoyable learning experiences can increase student motivation and academic achievement. The results of this study align with findings from various previous studies. Oktaviani et al. (2022) found that Augmented Reality-based learning media using Assemblr Edu had a very high level of validity with a practicality result of 90.38%. Iskandar and Mayarni (2022) also showed that the use of AR in science learning in elementary schools can significantly improve learning outcomes compared to conventional methods. Furthermore, Ramadhani et al. (2020) in their research on chemistry learning found that the use of AR-based modules helped students understand abstract molecular concepts through three-dimensional visualizations. These results strengthen the findings of this study that AR plays a major role in improving conceptual understanding and student learning outcomes in abstract material.

Theoretically, improving student learning outcomes through the use of AR-based media can be explained through the Cognitive Theory of Multimedia Learning (Mayer, 2009). This theory explains that the human brain has two main channels for processing information: the visual channel and the verbal channel. When these two channels are used simultaneously, information can be processed more efficiently and result in better understanding. AR media combines both through three-dimensional visual displays accompanied by narratives and explanatory text, thereby helping students build strong mental representations of the concepts being learned. In addition, the results of this study also support the principles of Constructivism Theory (Piaget, 1973), which emphasizes that students construct their knowledge through direct experience and interaction with the environment. Through AR media, students can actively explore geosphere phenomena such as the water cycle on earth in a more realistic and contextual way. This enables a meaningful learning process, where the knowledge gained is not only remembered temporarily but also understood and can be applied to other contexts.

From an affective perspective, this media has been shown to increase student motivation and engagement in the learning process. Students demonstrated a high level of curiosity, actively participated in discussions, and felt more confident in answering teacher questions. This finding aligns with Musfiqon's (2012) opinion, which states that technology-based learning media can stimulate learning interest and increase student participation because it provides a fun learning experience that differs from conventional learning. Practically, the results of this study have a positive impact on improving the quality of geography learning in schools. Teachers can use this media as a tool in explaining abstract geosphere concepts, while students gain a more interactive and applicable learning experience. The use of Google Sites also makes it easier for teachers to integrate various digital learning resources such as videos,

images, and AR simulations into one easily accessible platform.

Thus, it can be concluded that the development of interactive geography learning media based on Augmented Reality (AR) integrated through Google Sites and Assemblr Studio has proven valid, practical, and effective in improving student learning outcomes in the hydrological cycle. This media not only helps students understand abstract material but also creates a learning experience that is enjoyable, motivating, and in line with the demands of 21st-century education.

CONCLUSION

This research resulted in an interactive geography learning media based on Augmented Reality (AR) designed to facilitate students' understanding of abstract concepts in the hydrological cycle. The media development was carried out using the ADDIE model which includes the stages of analysis, design, development, implementation, and evaluation. The development process resulted in a final product in the form of digital learning media integrated through Google Sites and Assemblr Studio, so that students can learn the hydrological cycle process visually, contextually, and interactively. The results of validation by experts showed that this learning media met the criteria of being very suitable for use in the geography learning process. Material experts gave a feasibility percentage of 98%, media experts 88%, linguists 84.6%, and education practitioners 95%. These findings indicate that in terms of content, appearance, language, and usefulness, the AR-based media developed is in accordance with learning needs and educational media quality standards.

A limited trial conducted on 35 grade X students of SMA Negeri 1 Labuhan Ratu showed a significant increase in learning outcomes. Based on the Paired Sample T-Test, the Sig. (2-tailed) value was obtained = 0.000 < 0.05, which means there is a significant difference between the pretest and posttest results. The average value of learning outcomes increased from 67.22 before using the media to 86.94 after learning using AR media. This proves that Augmented Reality-based learning media is effective in improving students' understanding of the hydrological cycle material. In addition to improving learning outcomes, the use of this media also increases students' motivation, involvement, and interest in learning. Students feel more enthusiastic and interested because they can directly see a three-dimensional simulation of the geosphere process through digital devices. Learning becomes more interactive, interesting, and not monotonous, thus encouraging students to actively participate in learning activities.

Theoretically, the results of this study support the Cognitive Theory of Multimedia Learning (Mayer, 2009) which states that learning is more effective when information is presented through a combination of visual and verbal, as well as the Constructivism Theory (Piaget, 1973) which emphasizes the importance of direct learning experiences in building knowledge. The AR media developed allows students to build their own understanding through exploratory experiences and concrete visualizations of abstract natural processes. Thus, it can be concluded that the development of interactive geography learning media based on Augmented Reality (AR) on the hydrological cycle material has been proven valid, practical, and effective for use in the learning process in secondary schools. This media is not only able to improve student learning outcomes, but also strengthen learning motivation and provide a fun and contextual learning experience.

This research makes a significant contribution to geography learning innovation in the digital age and can serve as an alternative solution for teachers in integrating technology into learning activities. For future research, it is recommended that this medium be developed for other geography materials, involving a wider sample, and incorporating digital-based evaluation elements to more comprehensively measure learning outcomes.

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