SCIENTIFIC PAPER

Augmented Horizons: Development and Impact of Augmented Reality on Atmospheric Education

Riska Susmei Rindantiya (✉), Zeni Haryanto, Iya' Setyasih

1Universitas Mulawarman, Samarinda, Indonesia
riskasusmei080@gmail.com

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ABSTRACT

Educational media serve as a supporting component in learning, offering benefits to enhance student engagement, interactivity, and interest in learning. The media employed should align with current advancements in science and technology, one of which is Augmented Reality (3D), a medium capable of projecting virtual objects into reality. This study aims to 1) Produce an AR media design for high school geography education on atmospheric topics, 2) Determine the feasibility of using AR-based media for such geography education. The creation of the Augmented Reality (3D) educational media utilizes the Borg and Gall (1989) model, which comprises ten development steps. This media creation employs Unity 3D software and supporting applications such as Vuforia, Cinema 4D, and Corel Draw. The development of this educational media resulted in two products: a smartphone application (for Android and iOS) named Cloud AR and its accompanying book, both of which meet UNESCO standards. Based on the research findings, the developed educational media is deemed suitable for use, with a score of 85.16% and classified in the suitable category.

KEYWORDS

Learning Media; Augmented Reality; Atmosphere

INTRODUCTION

The learning process today is increasingly geared towards being interactive, engaging, enjoyable, and challenging, aimed at nurturing students' creativity and independence in alignment with their talents and interests (Putra dkk, 2023). A significant factor in the enjoyment and efficacy of learning activities is the choice of educational media, which must not only be appealing and interactive for students but also maintain the integrity of the educational content (Andarukmi dkk, 2024). As technology continues to evolve, impacting various facets of human life, it has brought about advancements in educational media, making them more immersive and informative without losing the essence of the material taught (Wijayanti dkk, 2024).

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Among these technological advancements, Augmented Reality (AR) emerges as a transformative tool, distinctly different from previous educational technologies due to its ability to merge virtual objects into the real-world environment in real-time (Putra dkk, 2021). This integration facilitates an immersive learning experience, allowing students to grasp abstract concepts through tangible, spatial interactions, thereby enriching their understanding and engagement with the material (Habibah dkk, 2023).

The accessibility of AR technology for educational institutions has significantly improved, thanks to advancements in pedagogical approaches, application development, technology, and the decreasing costs of hardware. These developments suggest that AR will become increasingly feasible and widespread in educational settings, providing a more interactive and effective learning environment (Garzón dkk, 2020).

For AR to be effective, it requires specific technical inputs such as videos, images, animations, and 3D models to create realistic visuals. This requirement has implications for content creators and educators, highlighting the necessity for them to develop or acquire content that meets these technical specifications to ensure an enriched learning experience (Arulanand dkk, 2020).

Technologies such as SLAM (Simultaneous Localization and Mapping), sensors, and depth measurement play a crucial role in AR's effectiveness, enabling the dynamic integration of virtual objects with the real world. This technology allows for interactive learning environments that can adapt in real-time to the learner's context, making the educational content not only accessible but also engaging (Romano dkk, 2023).

The capability of AR to enhance the presentation of educational content, such as making atmospheric phenomena like clouds appear in 3D, exemplifies its potential to make learning more vivid and understandable. This approach to education demonstrates how AR can transform abstract concepts into tangible experiences, significantly improving comprehension (Huang dkk, 2022).

The choice of educational media has a profound impact on learning outcomes. Engaging and interactive media, particularly AR, has been shown to enhance learning by stimulating multiple senses and actively involving students in the learning process. This engagement is vital for improving learning outcomes, fostering a deeper understanding (Ramadhan, 2024), and ensuring the retention of educational content (Aulia dkk, 2024).

Recent studies continue to underscore the relevance and potential of AR in enhancing academic education and training. By providing timely information and rich, dynamic content, AR has demonstrated its ongoing utility in making education more efficient and engaging (Arif dkk, 2024).

Looking forward, AR holds immense potential for further development in the field of education. Its ability to revolutionize the delivery and experience of educational content offers exciting prospects for future teaching and learning innovations (Kamińska dkk, 2023).

The choice of the research location was influenced by observations that teachers at SMA Negeri 8 Samarinda in geography learning primarily relied on worksheet tasks without substantive explanation, leading to a noticeable lack of enthusiasm among students. This scenario underscores the potential of AR to reinvigorate interest and engagement in geography learning by providing a more
interactive and immersive learning experience, thus addressing the identified gap in educational engagement.

**METHOD**

In this research and development study, often abbreviated as R&D, a systematic approach is essential for the creation of new products or processes. Contrary to the ten stages of development outlined by Borg & Gall (1989), this research selectively employs seven critical stages for the development of augmented reality media in education: preliminary study and information gathering, research planning, product development, validator trial, user trial, product revision, and final product. This selection and enumeration error in the initial manuscript is corrected here for clarity and to emphasize the rationale behind choosing these particular stages, which are tailored to effectively address the specific needs and objectives of developing educational AR media.

The subjects of this study include geography teachers and tenth-grade social science students, who were divided into two trial groups to evaluate the AR media. The choice of these subjects and the structuring into small (3 students) and large (7 students) group trials were strategically made. Geography teachers bring expert insight into the subject matter, ensuring the content's relevance and applicability, while tenth-grade social science students represent the primary audience for the AR media, making their feedback critical for assessing its engagement and educational value. The small group trial allows for a focused, detailed collection of feedback, while the large group trial provides broader insights into the AR media's applicability and scalability.

For data collection, both open and closed questionnaires were employed. Open questionnaires targeted content expert validators, media expert validators, and language expert validators, selected for their specialized knowledge and expertise in their respective fields. This choice ensured a comprehensive evaluation of the AR media's content, presentation, and linguistic accuracy. Closed questionnaires were administered to teachers and students to assess the developed product's feasibility and effectiveness, serving as a foundation for further development.

The study utilized a descriptive data analysis technique, chosen for its suitability in evaluating the collected qualitative and quantitative data. This approach allowed for the analysis of feasibility assessment data through average calculations, providing a straightforward method for determining the educational media's effectiveness. Quantitative data, transformed into descriptive percentages, were interpreted into qualitative assessments, offering a nuanced understanding of the AR media's impact. This conversion process, detailing how averages and percentages are calculated and applied, underscores the methodological rigor of the study.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Score (%)</th>
<th>Qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>81-100</td>
<td>Suitable</td>
</tr>
<tr>
<td>B</td>
<td>61-80</td>
<td>Moderately suitable</td>
</tr>
<tr>
<td>C</td>
<td>&lt;60</td>
<td>Unsuitable</td>
</tr>
</tbody>
</table>

Source: (Modifikasi, Akbar 2013)

For calculating the feasibility of educational media products, the formula used is as follows.
Future Space: Studies in Geo-Education

\[
p = \frac{\sum x}{\sum xi} \times 100 \%
\]

Description:

\( P \) = Assessment percentage

\( \Sigma x \) = Total number of respondent answers in one aspect

\( \Sigma xi \) = Maximum score in 1 aspect

100\% = Constanta

RESULT AND DISCUSSION

Result

This research and development effort has culminated in the creation of two primary products: an augmented reality application and a supplementary book, both designed specifically for high school geography education. The augmented reality application represents a forward step in digital learning media, compatible with Android and iOS smartphone devices. It is complemented by a supplementary book that facilitates the display of three-dimensional content, directly addressing the educational needs of high school geography students and setting a clear context for its application (İbili dkk, 2020).

1. Feasibility of Developed Augmented Reality-Based Educational Media

The feasibility stage of the educational media development is crucial for evaluating its effectiveness and utility. This phase involves a detailed presentation and analysis of data derived from the development process of the geography educational media (Adedokun-Shittu dkk, 2020).

2. Data Presentation

Data presentation encompasses a comprehensive display of results obtained from the product trials, which include both validation results from expert validators and outcomes from user trials involving teachers and students. This approach ensures a multifaceted evaluation of the educational media’s feasibility (Christopoulos dkk, 2021).

3. Product Validation Results

The validation of the product was meticulously conducted by individuals proficient in content, media, and language, ensuring a thorough assessment of the augmented reality application and the supplementary book. These validators, known as content experts, media experts, and language experts, employed a set of predefined criteria to examine various aspects of the products (Nassereddine dkk, 2022).

Table 2. Product Validation Data provides a detailed account of the feedback received from each type of validator. The feedback ranged from suggestions for improvements to specific components of the products, such as definitions, image quality, and information clarity, to more general advice on presentation standards like font improvements and adherence to linguistic guidelines.
The criteria used by the material expert validators were particularly aligned with the overarching objectives of educational media development. These included the clarity and coherence of content within the supplementary book, the congruence between three-dimensional objects and the content, and the overall congruence of learning media development with the educational content (huang dkk, 2022). This alignment ensures that the developed media not only meets technical and aesthetic standards but also effectively supports the educational goals of high school geography.

Validation Process and Criteria: The validation process involved a rigorous examination of the products based on a comprehensive set of criteria covering content accuracy, media presentation, and language use. These criteria were meticulously designed to ensure that the educational media not only adheres to high standards of quality but also aligns with the educational needs and maturity level of high school students (Liu dkk, 2024).

Data Presentation and Evaluation Criteria: The presentation of data from the product trials was structured to provide clear insights into the effectiveness and reception of the developed media. This involved a detailed analysis of feedback from both expert validators and end users, ensuring a thorough understanding of the media's strengths and areas for improvement (Zhao dkk, 2023).

Validation Criteria and User Trial Scope: Further detailing on the validation criteria and the scope of user trials highlighted the comprehensive approach taken to assess the educational media's feasibility. This included a focus on both the technical aspects of the augmented reality application and the educational effectiveness of the supplementary book, ensuring a holistic evaluation of the products' impact on high school geography education (Liu dkk, 2024).

### Trial Results by Practitioners and Users

1. **Product Evaluation by Practitioners (Teachers)**

   Practitioners, specifically teachers, played a pivotal role in the evaluation process, providing critical feedback on the augmented reality application and supplementary book through a structured closed questionnaire. This feedback is integral to the developmental process, offering insights into the practical application and educational value of the product in real-world settings. The practitioners' evaluations across three key aspects—usage instructions, material, and three-dimensional objects—underscore the product's suitability for high school geography education, with each aspect receiving scores indicating strong approval. The importance of this feedback cannot be overstated, as it directly influences subsequent revisions and enhancements to ensure the product meets the exacting standards of educational practitioners.

   ![Table 3](image)

   Table 3. Trial results of the product by practitioners
Based on the trial results of the product by practitioners, it is evident that the learning media across each evaluation aspect is deemed suitable. This suitability is evidenced by scores >81% in each evaluation aspect, including usage instructions, material, and three-dimensional objects, thus categorizing them within the suitable range. However, the aspect of three-dimensional objects scored the lowest at 82.35%. This was attributed to the time constraints encountered during the development of the learning media.

2. Product Evaluation by Students

The student evaluation process, mirroring that of the practitioners, employed a closed questionnaire designed to capture succinct, quantitative data on the product's usability, educational content, and three-dimensional representation. The choice of a closed questionnaire was motivated by the need for methodological consistency and the ability to directly compare feedback across different user groups. This approach facilitates a clear understanding of the product's impact from the learner's perspective, highlighting areas of strength and opportunities for improvement (Daniela, 2020).

3. Usage Instructions

The detailed tabulation of scores related to usage instructions reveals areas where the product could be enhanced to better support user engagement and comprehension. These findings are crucial for refining the product's design to ensure that instructions are not only clear but also conducive to effective learning (Wang dkk, 2022). The implications of these scores are carefully considered in relation to the development goals, guiding targeted improvements to make the product more user-friendly and effective as an educational tool.

Table 4. Explanation of the assessment results of the instructions for use

<table>
<thead>
<tr>
<th>Assessment Aspect</th>
<th>Score (%)</th>
<th>Qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding the instructions for use</td>
<td>72.72</td>
<td>Decent enough</td>
</tr>
<tr>
<td>The suitability of the stages of using learning media with instructions</td>
<td>66.67</td>
<td>Decent enough</td>
</tr>
<tr>
<td>Clarity of sentences in the steps of using learning media</td>
<td>64.00</td>
<td>Decent enough</td>
</tr>
<tr>
<td>Clarity of images in the steps of use</td>
<td>69.56</td>
<td>Decent enough</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>68.23</strong></td>
<td><strong>Decent enough</strong></td>
</tr>
</tbody>
</table>

Based on the table, it is stated that the average score obtained in the usage instructions assessment aspect is 68.23%, thus categorizing it within the moderately suitable range.

4. Material

Evaluation of the material aspect highlighted the product's strengths, particularly in terms of the attractiveness and clarity of images and the comprehensibility of the content. However, a deeper analysis of the areas receiving lower scores reveals specific opportunities to enrich the educational content and presentation. This nuanced understanding of the product's material component is essential for driving enhancements that directly address users' needs and preferences (Kang dkk, 2023).
Based on the table, it is stated that the average score obtained in the material assessment aspect is 87.62%, thus categorizing it within the suitable range.

5. Three-Dimensional Objects

The assessment of three-dimensional objects by both practitioners and students provided valuable feedback on the product's innovative use of AR technology. Clarification on the alignment of statements used for evaluations by both groups supports the validity of the comparative analysis, ensuring that the feedback accurately reflects the product's effectiveness in enhancing learning through three-dimensional visualization (Rodrigues dkk, 2020).

Based on the table, it is stated that the average score obtained in the three-dimensional object assessment aspect is 89.29%, thus categorizing it within the suitable range.

Given the evaluations across each outlined assessment aspect, including usage instructions, material, and three-dimensional objects, an average score of >81% was achieved, classifying each assessment aspect as suitable. The data from the student evaluations can be viewed in the table below.

<table>
<thead>
<tr>
<th>Assessment Aspect</th>
<th>Score (%)</th>
<th>Qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructions for use</td>
<td>68,23</td>
<td>Decent enough</td>
</tr>
<tr>
<td>Material</td>
<td>87,62</td>
<td>Worth</td>
</tr>
<tr>
<td>3-Dimensional Objects</td>
<td>89,29</td>
<td>Worth</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>81,71</strong></td>
<td><strong>Worth</strong></td>
</tr>
</tbody>
</table>
Based on the table, it is noted that the overall student assessment of the learning media yielded an average score of 81.71%. Consequently, the overall student evaluation of the learning media falls within the suitable category.

6. Evaluation of the Product by Teachers and Students

The comparative analysis between teacher and student evaluations offers a comprehensive perspective on the product's educational impact. This diversity of feedback is instrumental in refining the final product, with each group's insights contributing to a balanced and effective educational tool. An in-depth discussion on how these perspectives have been integrated into the final evaluation deepens the analysis, showcasing the product's capacity to meet varied educational needs and preferences (Jiang dkk, 2020).

<table>
<thead>
<tr>
<th>Assessment Aspect</th>
<th>Score (%)</th>
<th>Qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructions for use</td>
<td>81.75</td>
<td>Worth</td>
</tr>
<tr>
<td>Material</td>
<td>87.92</td>
<td>Worth</td>
</tr>
<tr>
<td>3-Dimensional Objects</td>
<td>85.82</td>
<td>Worth</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>85.16</strong></td>
<td><strong>Worth</strong></td>
</tr>
</tbody>
</table>

The table above indicates that the trial results for users across each assessment aspect, such as usage instructions, material, and three-dimensional objects, achieved scores of >81%. The highest score was obtained in the material aspect, with a score of 87.92, while the lowest score was found in the usage instructions aspect, with a score of 81.75%. Based on the evaluations presented in the table for each assessment aspect, the average result of the user trials is 85.16%, thus classifying the produced learning media and supporting books as suitable within the category.

Discussion

1. Learning Media Development Results

This research has successfully yielded two main outputs: a learning media application and a supporting book. The concise articulation of these outcomes lays a solid foundation for an in-depth examination of their contributions to geography education (Guo dkk, 2024). The CloudAR application, an innovative augmented reality (3D) tool designed for both Android and iOS smartphones, stands out for its educational utility (Fajrianti dkk, 2021). This app, requiring 59 MB of storage and a 5 MP rear camera for operation, is tailored for offline use, ensuring accessibility without an internet connection. A more detailed exploration of CloudAR's specific educational functionalities reveals its capacity to bring geographic concepts to life, offering students a tangible and interactive learning experience that traditional methods cannot provide.

The development and trial phases of CloudAR and the supplementary book encountered several challenges, notably delays in generating 3D images for certain cloud types during CT scans. Reflecting on these obstacles, it becomes apparent that addressing or mitigating such issues in future iterations could significantly enhance the product's reliability and user experience (Siriwardhana dkk, 2021).

The benefits of CloudAR, including its realistic display of various cloud types and its portability, directly impact the learning process by making abstract geographical concepts accessible and engaging. Expanding on how these advantages enrich the educational experience reveals the application's potential
to transform geography learning into an immersive and interactive process (Gómez-Galán dkk, 2020).

The technical specifications required for creating the CloudAR media, such as the need for a laptop with more than 4 GB of RAM, over 2 GB of VGA, and a 1 TB hard disk, highlight the technological demands of developing high-quality augmented reality content. A discussion on how these specifications influence the application’s performance and development process sheds light on the intricate balance between technological capability and educational innovation.

2. Learning Media Suitability

The CloudAR application and its accompanying book have been rigorously evaluated, achieving an 85.16% suitability score from experts in media, material, and language. This high level of suitability underscores the product’s effectiveness as an educational tool, validated through comprehensive trials involving both teachers and students in varied classroom settings. Feedback from these trials has pointed towards avenues for further refinement, such as the expansion of the application’s features and the enhancement of its interactive visual objects.

Elaborating on the translation of this suitability score into tangible educational outcomes reveals the broader implications of the CloudAR media for geography education. The engaging and user-friendly nature of the application, coupled with its realistic visuals, not only supports the learning process but also opens up new possibilities for exploring geographical concepts in an interactive and meaningful way (Lampropoulos dkk, 2020).

In conclusion, the development of the CloudAR application and supporting book represents a significant advancement in geography education, offering a compelling example of how augmented reality can enhance learning outcomes. By addressing the technical and pedagogical challenges encountered during its development, this research contributes valuable insights into the ongoing evolution of educational technology.

CONCLUSION

The culmination of this research in the field of Atmospheric studies has led to the creation of two pivotal educational resources: the CloudAR learning media application and an accompanying supporting book. CloudAR, an augmented reality (3D) application, stands out for its smartphone compatibility across both Android and iOS platforms, embodying the cutting edge of digital educational tools. The inclusion of a supporting book, enriched with 3D images and comprehensive explanatory notes on each topic, is not merely an adjunct feature but a deliberate pedagogical choice. This dual approach intertwines the immersive experience of augmented reality with the depth of traditional learning materials, facilitating a multifaceted learning experience. The pedagogical rationale behind this blend of 3D visualization and detailed narrative is grounded in the understanding that different learners engage with content in varied ways. The 3D images offer an immediate, visual comprehension of atmospheric phenomena, particularly cloud types, while the explanatory notes provide the contextual depth and detail necessary for a thorough understanding. This strategy ensures that learners not only visually grasp the subject matter but also intellectually engage with it, fostering a comprehensive learning experience that is both engaging and informative.
The assessment of the developed learning media, yielding an average suitability score of 85.16% from trials conducted with practitioners and students, signifies its effectiveness and appropriateness for educational use. This suitability rating, affirming the educational value of the CloudAR application and supporting book, suggests a promising avenue for the future of educational media development. The implications of this rating extend beyond the immediate success of the project, indicating a broader applicability of augmented reality technologies in educational settings. It encourages future endeavors to explore similar innovative approaches that blend technological advancements with pedagogical insights, aiming to enhance student engagement and learning outcomes further. As educational practices continue to evolve with technological advancements, the findings from this research offer a forward-looking perspective, highlighting the potential of augmented reality and supportive printed materials in creating immersive and comprehensive educational experiences.

REFERENCES


Rindantiya dkk


**AUTHOR**

Riska Susmei Rindantiya, currently enrolled in the Geography Education program at Universitas Mulawarman, exhibits a profound commitment to the exploration and understanding of geographic principles and their educational implications. Her academic pursuits are characterized by a diligent and analytical
approach to comprehending the complex interactions between natural environments and human societies (email riskasusmei080@gmail.com).

**Zeni Haryanto**, a distinguished student within the Geography Education department at Universitas Mulawarman, where he has demonstrated exceptional aptitude in both physical and human geography (email zeniharyanto2@gmail.com).

**Iya’ Setyasih**, pursuing a degree in Geography Education at Universitas Mulawarman, stands out for her innovative approach to geographical research and education. Specializing in the use of geographic information systems (GIS) in educational settings, Iya aims to enhance the learning experience by incorporating technology and spatial analysis into the geography curriculum (email setyasih.iya57@gmail.com).