Development of Pop-up Book-Based Learning Media Utilizing Augmented Reality for Science Subjects

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Abstract: The role of teachers in education goes beyond simply delivering teaching materials. A teacher must create an exciting and interactive learning atmosphere that captivates students' attention and encourages active participation in learning. Teachers often face challenges in creating engaging and relevant learning materials while integrating the latest technology, which can impede the achievement of learning goals and reduce the effectiveness of the teaching-learning process. A significant issue is the lack of student motivation and involvement, evident from boredom and inattention despite using various learning resources. This study aims to address this issue by developing a Pop-Up Book-based learning media utilizing Augmented Reality (AR) for science subjects in Grade V Elementary School. The research was conducted at SDN Pandanwangi 3 and followed the ADDIE development model—Analysis, Design, Development, Implementation, and Evaluation. The findings indicate that the AR-based Pop-Up Book is effective in enhancing the quality of learning. Implementing this media at SDN Pandanwangi 3 successfully motivated students, improved their understanding of the subject matter, and demonstrated high practicality according to questionnaires and learning outcomes. The final evaluation confirms that this media is valid, practical, and effective in meeting learning objectives. It is recommended that AR-based learning media, such as Pop-Up Books, be extended to other subjects and educational levels. Further research is suggested to explore the effectiveness of such media across different contexts and disciplines, ensuring broader applicability and impact in academic settings.

Keywords: Augmented reality (AR); Developing Media; Interactive Learning Media; Pop-up Book.

Introduction

The role of teachers in education goes beyond simply delivering teaching materials [1]. A teacher must create an engaging and interactive learning atmosphere that captivates students' attention and encourages active participation in the learning process [2]. Teacher creativity becomes critical to achieving this goal because, with an innovative and adaptive approach, teachers can present the material as more exciting and relevant for students [3]. This creativity helps increase student engagement and deepens their understanding of the material being taught, allowing students to internalize knowledge and apply it in a broader context [4]. Thus, the role of teachers as creative and inspiring learning facilitators is vital in supporting educational success.

One innovation that can be used is the development of technology-based learning media, such as Pop-up books combined with Augmented reality (AR). This medium offers a new way to visualize complex concepts, allowing students to see a dynamic three-dimensional representation of the subject matter, which can significantly improve their understanding. With their stimulating visual effects, pop-up books attract students ' attention but also help them build stronger visual connections with abstract concepts in science learning [5]. Coupled with AR elements that add a layer of virtual reality, this medium can bring students closer to immersive and realistic learning experiences, mimicking the real-world situations they are learning about. The use of AR-based Pop-Up Book media in primary education has the potential to support learning in science, mainly because of its ability to stimulate students ' imagination and make learning more exciting and meaningful [6]. Implementing this technology requires careful preparation, including developing 3D models and appropriate frameworks, to become an effective auxiliary tool in the learning process[7].

AR-based media in primary education shows excellent potential to support science learning in a more engaging and meaningful way [8]. One feature that can increase this media's effectiveness is the integration of a Quick Response Code (QR Code). QR Code, introduced by the Japanese company Denso Wave in 1994, was initially used to track the inventory of auto parts production. QR codes have evolved into a multifunctional tool used in various industries for marketing and promotion and to access information quickly and efficiently. By scanning the QR Code integrated into the Pop-up Book media, users can access the latest and interactive content, connecting printed information with a dynamic digital experience. Incorporating QR codes in AR-based Pop-Up Book media expands students' access to information. It allows them to interact with the subject matter directly, making it a more effective tool in supporting the learning process. Thus,

using QR codes in this context can enrich the learning experience and make it more interactive and relevant.

Using Augmented reality (AR) to complement science education in the fifth grade can make the presentation of the material more interesting and understandable [9]; with AR, students can experience original events in the form of captivating animations, thereby increasing their involvement in the learning process. This technology allows educators to teach more modern and digital, making lessons more relevant to current technological developments [10]. Interactive learning Media that utilize AR can strengthen students ' critical thinking skills, positively impacting their learning outcomes [11]. This technology's engaging animations help students understand the subject matter better and faster [12]. AR is gaining popularity due to its ability to show 3D media via smartphones or PCs, which is an ideal choice for developing learning media [13]. To ensure greater accessibility, Learning media is packaged in the form of AR-based pop-up books, which integrate technology with a format that is easy for many learners to use.

Based on initial observations made by researchers at SDN Pandanwangi 3, especially in the fifth class, students are less active, bored, and pay less attention to the teacher's explanation during the learning process. Although teachers put a lot of effort into attracting students ' attention by using various learning resources such as PowerPoint, whiteboards, and printed drawings, the results appear substandard, and students lack enthusiasm for learning. This problem is exacerbated by the lack of interesting educational materials, which hinders students from understanding the lesson well. Teachers admit they have not fully mastered the latest technology and often find integrating digital-based media in learning difficult. This leads to limitations in creating educational materials that are interesting and relevant to students. Given this problem, it is clear that using technologies such as Augmented reality (AR) can be an effective solution. AR technology can transform the learning experience by presenting subject matter more interactively and engagingly.

Interactive learning Media supported by digital technology has great potential to improve students ' critical thinking skills. By integrating this technology, learning media not only becomes more exciting and relevant but can also overcome the problem of boredom and inattention of students identified in the observation. Therefore, this study aims to develop technology-based learning media, namely AR-based Pop-up books, for science subjects in the fifth grade of Elementary School. This media is expected to create a more dynamic, enjoyable, and practical learning experience, thus supporting the achievement of learning goals and improving student learning outcomes.

Research Methods

This research was conducted on Elementary School students of SDN Pandanwangi 3 fifth class in science. The following stages in this study are presented in Table 1, which consists of 5 stages.

Data collection instruments consist of validation sheets used to measure the validity of the product questionnaire responses of students and teachers to measure the practicality of the media pulpit. The researchers used a Likert rating scale of 1-5 to determine the product's validity and practicality level. For the scores (1) strongly disagree, (2) disagree, (3) neutral; (4) agree; and (5) strongly agree. Here is a description of the technical data analysis in this study.

Table 1. Research Stage

No	Phases Of Research	Activities
1.	Analyze	At this stage, the researchers analyzed the development of AR-based learning media. Analysis activities consist of Needs Analysis, Analysis of the learning environment at school, analysis of student characteristics, and analysis of learning objectives.
2.	Design	At this stage, the researchers compiled a flowchart about the flow of media to be developed. The design is prepared by studying the problem and then finding a solution through identification based on the analysis stage. The next step is determining the learning strategy and design of Learning media embodied in storyboards.
3.	Development	In the development stage, the researcher embodies the design of the storyboard. Researchers develop and design AR-based media from the collection of information that has been obtained in the previous stage.
4.	Implementation	At this stage, AR-based media is implemented in the learning process. The primary purpose of the implementation phase is to guide students in achieving learning objectives and ensure that students acquire competence, knowledge, and skills at the end of learning.
5.	Evaluation	In the evaluation phase, the researchers used a summative evaluation model implemented at the end of the lesson to improve the overall effectiveness of AR-based media compared to other products.

Sources: [15]

Validity Data Analysis

$$V = \frac{f}{N} \times 100\% \ [27]$$

Description:
V = % Validity
∑f = total score of aspects received
N = total score
The percentage of validity tests is adjusted to the criteria.

Table 2. Validity Criteria

Percentage (%)	Interpretation
$0 \leq V \leq 20$	Very Invalid
$21 < V \leq 40$	Invalid
$41 < V \leq 60$	Quite Valid
$61 < V \leq 80$	Valid
$81 \leq V \leq 100$	Very Valid

Sources: [24]

Practicality Data Analysis

Researchers used teacher and student response questionnaires, which were filled in for each statement in the questionnaire and gave ratings of 1-5.

$$P = \frac{f}{N} \times 100\%$$

P = % Practicality
∑*f* = total score of aspects received
N = Total Score
The percentage of validity tests is adjusted to the criteria.

Table 3. Practicality Criteria

Percentage (%)	Interpretation
$0 \leq V \leq 20$	Impractical
$21 < V \leq 40$	Less Practical
$41 < V \leq 60$	Quite Practical
$61 < V \leq 80$	Practical
$81 \leq V \leq 100$	Very Practical

Sources: [25]

Effectiveness Data Analysis

Researchers used LKPD. Test questions are an instrument for measuring product effectiveness and are given to students at the end of the meeting. The product is declared effective if the student's test results reach the school's KKM score of 75. KKM is an abbreviation for Minimum Completeness Criteria, the lowest score students must achieve to be declared complete. The education unit determines KKM and refers to graduate competency standards.

$$E = \frac{S}{N} \times 100\%$$

E = % Of Learning
S = complete learners
N = Total number of participants
The percentage of test validity is adjusted to the criteria.

Table 4. Effectiveness Criteria

Percentage (%)	Interpretation
$0 \leq E \leq 20$	Very Ineffective
$21 < E \leq 40$	Less Effective
$41 < E \leq 60$	Quite Effective
$61 < E \leq 80$	Effective
$81 \leq E \leq 100$	Very Effective

Sources: [26]

Results and Discussion

The following are the results of research based on the ADDIE (Analysis, Design, Development, Implementation, Evaluation) development model.

At the analysis stage, an analysis of needs and materials is carried out. In the needs analysis, the researchers conducted observations and interviews with fifth-grade teachers at SDN Pandanwangi 3 to determine the needs for teaching materials and the characteristics of learners. The result is that the teaching materials come from the package book and the internet. Learners from the observation results showed a lack of motivation to learn, which impacted their learning outcomes. Researchers

analyze materials used to identify learning outcomes, flow, and learning objectives by meeting the needs of learners and curriculum demands [16].

At the design stage, the researchers prepared the material and made a storyboard based on needs analysis and material analysis that had been done before. The process begins by identifying the specific needs of the users, i.e., students and teachers, through in-depth needs analysis. This analysis includes understanding students' challenges in understanding the subject matter and how they interact with the current material. In addition, the researcher also assesses the existing subject matter, including complexity, relevance, and how it is delivered.

Figure 1. Augmented Reality's Product

Figure 2. Pop-up book product

The creation of a storyboard is the next step in the design stage. The storyboard serves as a blueprint for the development of learning media. These storyboards visually describe the flow and structure of the material, including interactive elements that will be integrated, such as animations or simulations based on Augmented reality (AR). In a storyboard, the researcher designs how each part of the material will be presented, how the student's interaction with the medium will occur, and how the transitions between the elements will occur. This includes the planned placement of visual elements, text, and interactive features, as well as how each section will support the learning objectives that have been set.

At the development stage, the researchers began to design augmented reality (AR) learning media using Assemblr Studio software and adjusted the illustrations for the material. Candidates must possess at least a bachelor's Degree in Engineering (Computer / Telecommunication), Engineering (Computer / Telecommunication), or equivalent. The assessment includes aspects of content, suitability of the scientific approach, didactic requirements, construction, and technical. The following are the

validation results of both validators, as presented in Table 4.

Table 4. AR Media Validation Results

Aspect	Percentage (%)		Average	Interpretation
	V1	V2		
Contents	84	88	86	Very Valid
Suitability of the Scientific Approach	80	80	80	Valid
Didactic Requirements	85	80	82.5	Valid
Terms of Construction	93	93	93	Very Valid
Technical Terms	100	100	100	Very Valid
Average	85.8	88.2	88.3	Very Valid

From the assessment of the two validators in Table 4, the average validity of the content aspect is 86%, the suitability of the scientific approach is 80%, didactic requirements are 82,5%, terms of construction are 93%, and technical terms are 100%. Overall, the average AR media Rating is 88,3%, a valid criterion. Thus, the developed media has fulfilled the aspect of validity. In addition, researchers also get comments and suggestions from both validators, as presented in Table 5.

Table 5. Validator comments and suggestions

Validator	Comments and suggestions	Revised Results
1	- AR Media atmospheric layer material less description - AR Media Animation is less interesting	- AR Media has been equipped with a description on each layer - More interesting animations have been added
2	AR Media is valid, but 3D media visualization needs to be improved	AR Media settings have been improved according to suggestions

At the implementation stage, the researchers applied AR-based learning media using Assemblr Studio software to 37 fifth-grade students at Sdn Pandanwangi 3, which had been repaired at the previous stage. Selection of SDN Pandanwangi 3 because the school still rarely uses interactive learning media that utilize digitization, especially in learning science. This affects the motivation of students, who tend to be less, so they cannot be considered able to meet the learning needs of students. The field test was conducted for one week on August 12-16, 2024. Researchers teach atmospheric layer materials using AR media. At the last meeting, researchers distributed questionnaires to students to obtain the results of AR media's practicality level. The following are the results of the questionnaire on the practicality of learners and teachers who are assessed in terms of language, presentation of the material, and attractiveness.

Table 6. Practicality Questionnaire Results

Aspect	Questionnaire Response (%)	
	Teacher	Learners
Language	95	83
Presentation of The Material	90	87
Attractiveness	95	82
Average	94	84

Based on Table 6 of the practicality questionnaire results, three aspects become practicality indicators: language, material presentation, and attractiveness. From the aspect of language, the questionnaire respondents' teachers got a score of 95; from the aspect of the presentation of the material, they got a score of 90; from the element of attractiveness, they got a score of 95 and an average score of 94. From the aspect of language, the results of the questionnaire responses from respondents Grade 5 students, as many as 37 of 50 students got a score of 83; from the aspect of the presentation of the material got a score of 87; from the element of attractiveness got a score of 82 and got an average value of 84. The results of the average Learning test of students who achieve learning completeness show that using LKPD increases students' understanding of the material. Based on the data in Table 6, LKPD with Pop-up Learning Media book AR, the atmosphere layer is included in the practical criteria based on the results of the questionnaire respondents and very practical criteria of the questionnaire respondents students according to Table 3.

Table 7. Student Learning Outcomes

Number Of Students Completed	Learning Outcomes Of Learners (%)
37	80.5

Table 7 shows that 37 students have reached or exceeded the KKM score based on student learning outcomes, meaning that 80.5% of students are declared complete. LKPD with Pop-Up Learning media book Ar atmospheric lamps are included in the effective criteria according to Table 4 effectiveness criteria.

At the evaluation stage, Validation of the results of the questionnaire teachers and students, as well as the results of the Learning test, showed that LKPD with Pop-Up Book AR learning media has met the criteria of validity, practicality, and effectiveness to be applied in science learning activities with the material layer of the Earth's atmosphere.

This research produces interactive learning media based on augmented reality (AR), developed using the Assemblr Studio platform. The Platform was chosen for its ability to support the creation of AR-based 3D media efficiently and effectively. Assemblr Studio offers a range of features that allow researchers to create AR media that is not only attractive but also functional, such as the ability to present immersive three-dimensional visualizations. Through AR, this learning medium creates a more accurate and interactive learning atmosphere, allowing students to see and interact with the subject matter in greater depth [17].

This AR-based Pop-up Book aims to increase student motivation and engagement in learning. With an

interactive display and attractive visualization, this media is expected to foster a high sense of learner curiosity. The use of AR in pop-up books not only motivates students to engage actively in learning but also encourages them to think critically and creatively [18]. When studying the layers of the Earth's atmosphere, students can see 3D representations of the different layers of the atmosphere integrated with animations that explain the functions and characteristics of each layer. This allows students to gain a better and more in-depth understanding of the subject matter [19]. Results development research in the form of learning media AR shows very good and feasible results when used as a learning medium, both in class or independently, according to the results of expert validation learning design, media experts, and teacher validation as a material expert. Student responses to The use of this media in learning is very Good. Students are enthusiastic about following learning and arousing curiosity student.[28] According to Antonioli et al. (2014: 96-107), AR can bridge the gap between practical and theoretical learning practices and real and virtual mixed components to create unique learning experiences.

In addition, AR-based interactive learning media also make it easier for educators to convey complex concepts [20]. By using AR, educators can visualize how the layers of the Earth's atmosphere form more clearly and dynamically. This medium helps deliver more effective material and provides a valuable tool to explain topics that may be difficult to understand through conventional methods. AR in Pop-up books allows teachers to show three-dimensional models of atmospheric phenomena, which can clarify and strengthen students ' understanding of the subject matter [21].

Overall, the development of AR-based interactive learning media in pop-up books shows excellent potential for improving student learning experiences [18]; [22]. Integrating AR technology and Pop-Up Book design provides an innovative and engaging approach to learning. This motivates students to be more actively involved in the learning process and facilitates a better understanding of the subject matter. Implementing this technology can be further adapted to different topics and levels of education, offering the opportunity to increase effectiveness and engagement in learning in the future [23].

Conclusion

Based on the results of this study that follows the development model ADDIE (Analysis, Design, Development, Implementation, Evaluation), it can be concluded that the development of Interactive Learning media based on Augmented Reality (AR) in the form of Pop-up Book proved effective in improving the quality of learning. The implementation of this media in SDN Pandanwangi 3 shows that using AR in Pop-up books can motivate students, enhance their understanding of the subject matter, and show high practicality based on questionnaires and learning outcomes. The final evaluation shows that this learning medium is valid, practical, and effective in achieving learning objectives. Thus, the AR-based Pop-up Book Learning media provides an innovative approach that increases student engagement and understanding and can be adapted for various topics and

levels of education in the future. It is recommended that AR-based learning media, such as Pop-up books, be extended to other subjects and levels of education. Further research can be conducted to explore the effectiveness of AR media in various learning contexts and disciplines.

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