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Developing augmented reality-based flashcards for early readers of elementary school

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ABSTRACT

Reading is a foundational skill that students must master from the early stages of primary education. However, observations at Public Elementary School 22 Sulur Medan revealed that many first-grade students struggle with reading fluency and often confuse alphabet letters. To address this issue, this study aimed to develop Augmented Reality (AR)-based flashcards as an innovative learning tool to support beginner reading instruction. The research objectives include assessing the reading abilities of first-grade students at Public Elementary School 22 Sulur Medan, designing the AR-based flashcard media, and evaluating its feasibility. This study employed the ADDIE development model within the framework of research and development methodology. Data collection techniques included observations, expert validations (content, pedagogy, and media), as well as feedback from student and teacher questionnaires. The findings demonstrated high feasibility ratings for the AR-based flashcards: 88% for content validation, 83% for pedagogical validation, 91% for media validation, 95% for student responses, and 95% for teacher responses, resulting in an overall score of 90% in the "Very Feasible" category. These results indicate that the AR-based flashcards are an effective tool for enhancing reading skills in first-grade students and offer a promising alternative for early literacy education.

1. Introduction

Reading skills are fundamental for acquiring knowledge and insights, significantly influencing a student's success in both academic and societal contexts [1]. These skills involve recognizing and understanding written words through cognitive processes, which facilitate effective written communication [2]–[4]. Reading can be broadly categorized into two types: beginning reading, which focuses on foundational skills taught in early grades, and advanced reading, encompassing comprehension, scientific writing, and creative expression [3], [5], [6]. As Rvachew *et al*, explains, beginning reading, typically introduced from grades 1 to 3, is a critical developmental stage where learners acquire the ability to recognize and vocalize written symbols accurately [5]. According to Romelah *et al*, key indicators of beginning reading skills include correctly pronouncing alphabet letters, reading vowels and consonants, forming syllables, decoding words, and articulating simple sentences with proper intonation [7]. Mastery of these foundational skills enables students to progress towards fluent reading [8]. However, despite the importance of these skills in elementary education, many students in grade 1 still struggle with reading fluency and letter recognition, as evidenced by observations at Public Elementary School 22 Sulur Medan. Challenges include difficulty spelling letters, stammering during reading, incorrect pronunciation, and unclear intonation, often linked to a lack of engaging and varied instructional media in classrooms [9]–[11]. To address these challenges, AR-based Flashcards provide a modern, effective solution by leveraging interactivity and engagement to bridge gaps in conventional learning methods.

Traditional Flashcards, while useful, may not fully captivate students or address their diverse learning needs, particularly when visual and auditory elements are absent. AR technology transforms these static tools into dynamic educational media that integrate animated visuals, sounds, and interactive features, fostering an immersive learning environment. For students struggling with letter recognition and reading fluency, AR-based Flashcards offer tailored reinforcement by presenting alphabet letters and sounds in engaging formats that align with their developmental stage. These features are particularly beneficial for addressing stammering, incorrect pronunciation, and unclear intonation, as students can repeatedly interact with the media at their own pace, strengthening their skills through repetition and feedback.

Effective learning media must be developed to address these challenges to enhance students' reading abilities. Learning media, defined as tools that facilitate teaching and learning processes, have been shown to boost student motivation [12]–[14]. Given that first-grade students are naturally drawn to visual and interactive content, Flashcards represent an ideal medium for early reading instruction [15], [16]. These simple, card-based tools combine images and text, making them suitable for conveying concepts and reinforcing learning [17]. With advancements in technology, Flashcards can be enhanced using Augmented Reality (AR), which integrates real-world elements with virtual animations to create interactive and engaging learning experiences. AR-based Flashcard media combine visual, auditory, and animated content, offering a dynamic approach to improving students' understanding of letters, words, and reading patterns [18]–[21].

Animated images contribute to early reading skills by visually representing letters, words, and related objects, making abstract concepts more concrete and memorable for young learners. This visual aid helps students associate symbols with their meanings, enhancing letter recognition and word decoding. Sound features further reinforce this learning by providing auditory examples of correct pronunciation and intonation, allowing students to hear and mimic proper reading patterns. Video tutorials offer step-by-step guidance for both students and parents, ensuring consistency in learning and providing a model for effective practice at home. Barcode scanning simplifies access to the learning materials, allowing students to independently explore interactive content with minimal guidance. Together, these features create a multi-sensory learning experience that keeps students engaged and supports the development of foundational reading skills.

Previous studies have demonstrated the effectiveness of Flashcards in improving early reading skills. For instance, [22] found that the institutional word method, supported by Flashcards, significantly enhanced early reading abilities among first-grade students in Bekasi. Similarly, [23] reported that Flashcards improved students' reading outcomes, with most participants achieving high test scores. Research by [24] also highlighted the feasibility and benefits of E-Flashcard media in enhancing science learning. Despite these successes, existing studies have not explored the integration of AR technology into Flashcard-based learning media for beginning reading skills in grade 1. This study aims to address this gap by developing AR-based Flashcards that incorporate interactive features, such as animated images, sound, and clickable elements, to engage learners more effectively. The innovation also includes video tutorials and barcode scanning for enhanced accessibility. The simplicity of these Flashcards makes them suitable not only for classroom use by teachers but also for independent learning under parental guidance. This research seeks to contribute to early reading education by offering an innovative, technology-driven solution to improve reading skills in first-grade elementary school students.

2. Method

This research employed the Research and Development (R&D) method, adopting the ADDIE development model as its framework. The ADDIE model consists of five sequential stages: Analysis, Design, Development, Implementation, and Evaluation [25]. Each stage was systematically executed to ensure the development and effectiveness of the AR-based Flashcard learning media for grade 1 students. The first stage, Analysis, focused on identifying needs through a comprehensive evaluation of students' reading challenges. This involved analyzing existing learning materials, the classroom environment, and the instructional tools currently used. These insights were critical for determining the specific requirements of the AR-based Flashcard media. The second stage, Design, involved gathering relevant materials and creating a detailed blueprint for the learning media. This phase prioritized aligning the design with grade 1 students' cognitive abilities by incorporating interactive elements and visually engaging features. The Development stage followed, where the initial prototype

of the AR-based Flashcards was created. The prototype underwent rigorous validation by experts in content, pedagogy, and media technology.

Validation instruments included detailed rubrics designed to assess three core aspects: content accuracy, pedagogical alignment, and media design quality. Content accuracy focused on the appropriateness and correctness of the materials provided, ensuring alignment with grade 1 reading standards. Pedagogical alignment examined how effectively the Flashcards supported the teaching-learning process, including student engagement and learning outcomes. Media design quality evaluated the visual appeal, interactivity, and functionality of the AR-based features, such as animated images, sound, and video tutorials. Each criterion was rated on a numerical scale, with additional qualitative feedback collected to guide iterative improvements. These evaluations ensured the media's quality, relevance, and usability. Once validated, the research progressed to the Implementation stage, during which the AR-based Flashcards were tested with 14 first-grade students from Public Elementary School 22 Sulur Medan. This stage was essential for observing student interactions and gathering feedback on the media's effectiveness and appeal. In the final stage, Evaluation, data from the trials and expert validations were analyzed to assess the learning media's feasibility. Revisions were made based on the findings to address identified weaknesses and optimize the product for classroom use. This iterative process ensured the AR-based Flashcards met the educational needs of first-grade students and their teachers.

The selection of 14 participants was based on the need for a manageable group size to facilitate detailed observation and interaction. Although the small sample size provided valuable insights into the practicality potential of the AR-based Flashcards, it is important to acknowledge this limitation. The results from this sample may not fully represent the broader population of first-grade students. However, the findings offer a foundational understanding of how AR-based Flashcards can address early reading challenges, which future research with larger samples can further validate and expand upon. Data collection involved a combination of observations, interviews, and questionnaires. Observations and interviews provided qualitative insights into the effectiveness and usability of the learning media, while questionnaires were used to gather quantitative data from expert validations and student and teacher feedback. Quantitative analysis evaluated expert validation results for content, learning methodologies, and media design, as well as the responses from students and teachers. Qualitative analysis, on the other hand, offered in-depth interpretations of observed and reported experiences.The study sample consisted of 14 first-grade students from Public Elementary School 22 Sulur Medan. These participants were selected to test the practicality and engagement potential of the AR-based Flashcards. This methodological approach, combining a structured development process with qualitative and quantitative analyses, provided a comprehensive framework for designing an innovative learning tool to enhance early reading skills among elementary students.

3. Results and Discussion

This section describes the results of the product development process through the stages of the ADDIE model: Analyze, Design, and Development, followed by insights from the Implementation and Evaluation stages.

3.1. Analyze

The analysis stage involved a thorough needs assessment, including an evaluation of students' interests and the availability of learning media in schools. Interviews and observations at Public Elementary School 22 Sulur Medan revealed that many grade 1 students struggle with fluent reading. Teachers also indicated that students show more enthusiasm for learning when media is incorporated into the lessons. However, due to limited resources, teachers relied primarily on textbooks as learning tools. Based on these findings, the researchers developed AR-based Flashcard learning media (Augmented Reality) to address these gaps. The media aimed to enhance early reading skills among grade 1 students, particularly in Indonesian language lessons focused on phase A of the topic *"Watch Out for Germs and Viruses."* This content includes reading exercises and activities that combine letter sounds into syllables and recognizable words.

3.2. Design

In the design stage, the framework for the AR-based Flashcard learning media was created. This process began with collecting relevant materials, primarily drawn from the grade 1 Indonesian language module for phase A. The module focuses on helping students read and blend letter sounds

into syllables and words. The AR-based Flashcards were designed with two interactive components. The first side displays alphabet letters alongside engaging animated images to capture students' attention. The second side includes a barcode that, when scanned, generates 3D animations and educational videos. These videos demonstrate letter recognition and sound blending, providing a multisensory learning experience. This interactive and visually appealing design was intended to make the learning process more engaging and effective for young learners.

3.3 Development

During the development stage, the AR-based Flashcard media was constructed according to the established design. The media was then subjected to expert validation, involving professionals in content, pedagogy, and media technology. This validation ensured that the media met educational standards and was suitable for the target audience. The prototype included alphabet letters, animated images, and barcodes linked to interactive videos. These components were crafted to support students in recognizing letters, combining them into syllables, and ultimately reading fluently.

- Material Expert Validation Results: The AR-based Flashcard media (Augmented Reality) underwent material validation to ensure its content was accurate, appropriate, and aligned with educational goals. The detailed results of the material expert's assessment are summarized in Table 1, which presents the evaluation criteria and corresponding scores. These findings provide critical insights into the strengths and areas for improvement in the AR-based Flashcard media, serving as a foundation for further refinement and development.

Table 1. Material Expert Validation Results

No.	Aspects Assessed	Total Score	Maximum Score	Percentage	Criteria
1	Contents	13	15	86%	Very feasible
2	Linguistics	9	10	90%	Very feasible
Total		22	25	88%	Very feasible

Based on Table 1, the material expert validation results for the AR-based Flashcard media (Augmented Reality) indicate a percentage score of 88%. According to the validity criteria, this percentage falls under the "very feasible" category, affirming the quality and appropriateness of the material for its intended use. Beyond the quantitative evaluation, the material expert provided valuable feedback to enhance the media. Specifically, it was recommended that the language used in the flashcards be simplified to align with the comprehension levels of grade 1 students. Additionally, it was advised to avoid using complex digraphs such as "NY" and "NG" to ensure the material remains accessible and easy to understand.

- Learning Expert Validation Results: Learning expert provided insights into the AR-based Flashcard media (Augmented Reality). Table 2 summarizes the assessment results from the learning expert, highlighting both strengths and areas for improvement.

Table 2. Learning Expert Validation Results

No.	Aspects Assessed	Total Score	Maximum Score	Percentage	Criteria
1	Material	18	20	90%	Very feasible
2	Media Quality	7	10	70%	Worthy
Total		25	30	83%	Very feasible

Based on Table 2, the learning expert validation results for the AR-based Flashcard media (Augmented Reality) show a percentage score of 83%. According to the validity criteria, this score also falls within the "very feasible" category, indicating that the media is generally suitable for use in educational settings. However, the learning expert provided additional feedback for improvement. It was suggested that the media would be easier to use if the AR-based Flashcards relied on available applications rather than the web, as scanning via the web was found to be time-consuming. This recommendation highlights the importance of accessibility, particularly for schools with limited internet access.

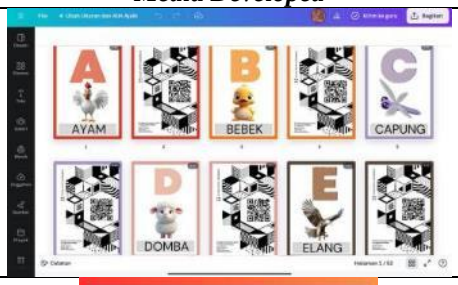
- Media Expert Validation Results: The validation of the AR-based Flashcard media was also conducted by a lecturer in the Elementary School Teacher Education Study Program (PGSD). The results of this assessment, summarized in Table 3, provide further insights into the media's effectiveness and areas for potential enhancement.

Table 3. Media Expert Validation Results

No.	Aspects Assessed	Total Score	Maximum Score	Percentage	Criteria
1	Quality	23	25	92%	Very feasible
2	Visual	8	10	80%	Worthy
3	Affective	4	5	80%	Worthy
4	Interactive	4	5	80%	Worthy
5	Barcode	5	5	100%	Very feasible
6	AR (Augmented Reality)	20	20	100%	Very feasible
Total		64	70	91%	Very feasible

Based on Table 3, the media expert validation results for the AR-based Flashcard media (Augmented Reality) show a percentage of 91%. This score falls within the "very feasible" category according to the validity criteria, indicating that the media is highly suitable for educational use. Additionally, media experts provided valuable suggestions to further enhance the product. Specifically, they recommended making the AR display more interactive and ensuring proper crediting of sources for the learning videos. These suggestions aim to improve user engagement and maintain academic integrity in the media. After obtaining the assessment results from the experts and making improvements to the learning media, the final product can be seen in Table 4.

Table 4. Flashcard Media Development Based on Augmented Reality

No.	*Media Developed*	*Description*
1		Flashcard Product Design
2		User Manual Design

No.	Media Developed	Description
3		Flashcard Box Design
4		Augmented Reality Display Design
5		Learning Video Display Design

3.4 Implementation

Following the revisions made based on the feedback from the expert validators, the next stage involved the implementation of limited product trials for the AR-based Flashcard learning media. This trial phase was conducted with a sample group consisting of grade 1 teachers from Public Elementary School 22 Sulur Medan and 14 grade 1 students from the same school.

- Teacher Response Results: The purpose of the teacher response assessment was to evaluate the effectiveness and implementation of the AR-based Flashcard media in a real classroom setting. The results of the teacher's assessment are summarized in Table 5.

Table 5. Teacher Response Results

No	Aspects Assessed	Total Score	Maximum Score	Percentage	Criteria
1	Attractiveness	20	20	100%	Very feasible
2	Ease	9	10	90%	Very feasible
3	Accuracy of Material	10	10	100%	Very feasible
4	Use of Language	18	20	90%	Very feasible
Total		57	60	95%	Very feasible

Based on the results presented in Table 5, the teacher response assessment of the AR-based Flashcard media (Augmented Reality) yielded a percentage of 95%. This score falls within the "very feasible" category according to the validity criteria, indicating that the media is highly effective and suitable for classroom use. In addition to completing the questionnaire, the teacher provided valuable feedback. The teacher highlighted that the AR-based Flashcard media is highly engaging, making it an enjoyable tool in the learning process. Moreover, it was noted that the media facilitates easier recognition of letters, contributing to students' early literacy development.

- Learner Response Results: The learner response assessment was conducted to gauge the students' reactions to, and experiences with, the AR-based Flashcard media. This evaluation was carried out by 14 grade 1 students at Public Elementary School 22 Sulur Medan. The goal of this assessment was to understand how the students engaged with the media and to gather their feedback on its effectiveness in supporting their learning. Based on the analysis of the student response questionnaire, the AR-based Flashcard media (Augmented Reality) received an overall score of 95%. According to the eligibility criteria, this score falls within the "Very Feasible" category, indicating that the students found the media both engaging and effective for learning. This positive feedback suggests a high level of interest and satisfaction with the AR-based Flashcard media among the students.

3.5 Evaluation

The evaluation phase of the product aimed to identify and address any shortcomings in the AR-based Flashcard media, particularly in relation to the adaptation of Indonesian language material. Following the trials with teachers and students, the feedback was thoroughly considered to ensure the media was of high quality and suitable for educational purposes. Despite receiving valuable input, no further revisions were required after the trial phase, as the product met the expectations and needs of both teachers and students.

- Product Discussion: The AR-based Flashcard learning media (Augmented Reality) has been designed to enhance early reading skills in grade 1 elementary school students. This innovative tool combines visual, audio, and AR technology to provide a dynamic learning experience. It is align with the findings of [26]–[28] who state that integrating real-world and virtual visuals, AR technology makes the displayed objects appear more lifelike, which is particularly engaging for young learners. The combination of visual and audio elements allows students not only to see but also to hear the corresponding sounds of letters, helping reinforce their recognition and pronunciation. The AR-based Flashcard media integrates animated images, videos, and sound, making it appealing to grade 1 students. This multimedia approach grabs their attention, making learning more interactive and enjoyable. Visual media relies on the sense of sight, with letter cards that students can observe, while audio media appeals to the sense of hearing, presenting the sounds of letters [29], [30]. This dual modality—sight and sound—enhances the learning experience by catering to different sensory channels, which can be more effective for young learners [28]. The combination of animated videos and letter recognition features enables students to practice word formation, building essential skills for early reading. In line with

educational best practices, the Flashcard media has been tailored specifically for grade 1 students, addressing their developmental needs [31], [32]. It includes letter recognition, animated images, and barcodes that can be scanned to display videos reinforcing letter sounds. Through this interactive approach, students can not only learn to read but also recognize the sounds associated with each letter, further solidifying their literacy foundation. This is consistent with research by [33]–[35], which emphasizes that learning videos facilitate easier comprehension of material [36]. The AR-based Flashcard media has undergone rigorous validation by material, learning, and media experts, who have deemed it both valid and feasible for use in early reading education. Their feedback, including suggestions on letter use, media thickness, and card size, has been incorporated to ensure the tool's practicality and effectiveness. After making the necessary adjustments, the AR-based Flashcard media has been confirmed as suitable for teaching beginner reading skills to grade 1 students. The average validity score from expert assessments was 90%, placing the media firmly in the "Very Feasible" category. In conclusion, the results indicate that the AR-based Flashcard learning media is an effective tool for enhancing the reading skills of grade 1 elementary school students. Its innovative use of augmented reality, coupled with animated visuals and sound, makes it not only educational but also engaging, ensuring it is both feasible and enjoyable for young learners. The product has been thoroughly reviewed and validated, confirming its potential to support the development of early literacy skills.

4. Conclusion

The AR-based Flashcard learning media developed for grade 1 elementary school students has been validated as an effective tool for supporting early reading skills. This media integrates AR technology to bring picture cards to life, combining visual and auditory elements to enhance learning. The Flashcards feature animated images, videos, and sound, all of which are designed specifically to align with the developmental needs of grade 1 students. The media was carefully assessed by experts in material, learning, and media fields, and received positive validation, confirming its feasibility and effectiveness. As a result, AR-based Flashcard learning media has been deemed "very feasible" for use in the classroom. Teachers can leverage this engaging tool to help students develop their early reading skills in a more interactive and captivating way. The findings underscore the potential of interactive tools in fostering motivation and sustained interest, which are critical for early literacy development. This research also provides a practical framework for combining pedagogy with cutting-edge technology, offering insights for educators and developers aiming to create impactful learning solutions. However, further research is needed to test the media's feasibility on a larger, more diverse sample of students and to compare it with other learning tools. The current study is limited by its small sample size, consisting of only 14 students, and its focus on a single school location. These factors may affect the generalizability of the findings. Expanding future research to include a broader demographic would provide additional insights into its broader applicability and effectiveness in various educational settings.

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Declarations

Author contribution	**:**	MTA was responsible for the whole research project. Along with the second, third, and fourth authors, he wrote and revised the manuscript. A, AU, and AB participated in the data collection, transcription, and analysis. All authors approved the final manuscript
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