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AR-Based Flashcards to Improve Primary School Students' English Vocabulary Mastery: Insights from Vocabulary Learning Research

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Abstract

This study aims to develop and test the effectiveness of Augmented Reality (AR) flashcards to improve English vocabulary mastery for 25 students in the fifth-grade primary school. The research method used is Research and Development (R&D) with the ADDIE development model that includes the stages of Analysis, Design, Development, Implementation, and Evaluation. Data collection was carried out through questionnaires, and vocabulary tests before and after treatment. The results of the study indicate that AR flashcards are very effective in supporting vocabulary learning. Validation by material experts showed a feasibility level of 93%, indicating that the content in this media is accurate, relevant, organized coherently, and appropriate to the level of cognitive development of students. Media experts also assessed AR flashcards as valid in terms of visual appearance and functionality. Teachers gave very positive responses, especially in aspects of media use and management in the classroom. Students showed high engagement, enjoyment, and increased learning motivation during learning with this media, although some experienced difficulties in understanding the language used. The test results showed a significant increase in vocabulary mastery, from 40% in the pre-cycle to 92% in the third cycle. These findings demonstrate that AR flashcards are effective and technologically innovative. The implications of this study suggest that AR flashcards can be an alternative contextual and student-centered learning medium in accordance with the Independent Curriculum. However, limitations include the limited number of subjects and the need for simplified language. Further research is recommended for broader coverage and long-term evaluation.

Keywords: AR–flashcards; English vocabulary; Teaching media; Primary students

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INTRODUCTION

Language is the primary means of communication in human life, whether in social, academic, or professional contexts. In learning a foreign language, particularly English as an international language, vocabulary mastery plays a crucial role as an initial foundation for developing language skills such as listening, speaking, reading, and writing (Richards et al., 2002). Harmer (2017) states that grammatical structure is the framework, while vocabulary is the content of the language. Therefore, students with a good vocabulary mastery tend to have an easier time understanding and expressing ideas in English. However, the reality on the ground shows that primary school students still face many obstacles in mastering English vocabulary because the teaching methods used are not appropriate to their characteristics and learning needs (Mutar, 2024).

Primary school-aged children, who are generally between the ages of 7 and 12, are in the concrete operational cognitive development stage (Afifah & Kusuma, 2021). At this

stage, their thinking begins to shift from imaginative to more logical and rationally acceptable concrete thinking. Therefore, in the learning process, they greatly need the assistance of tangible objects or media to better understand the concepts being presented (Dewi & Suniasih, 2022; Irawati & Setyadi, 2021). The effectiveness of the learning process itself is influenced by various aspects, including the teacher, students, learning media, and the learning environment. Learning media serves as a means of communication between educators and students, conveying information and learning messages to support the achievement of instructional goals (Handayani et al., 2020; Widiarti et al., 2021). The role of media in education is also very important in encouraging the creativity of both teachers and students, especially in the context of integrating technology to answer challenges and developments in the digital era (Antara & Dewantara, 2022; Rizaldi et al., 2020). In addition, the use of media can help teachers visualize abstract concepts, so that the lesson material becomes easier for students to understand.

A number of previous studies have revealed that the use of Augmented Reality (AR) technology in an educational context makes a positive contribution to the effectiveness of learning (Madanipour & Cohrssen, 2020; Xue & Wang, 2021). By presenting diverse content tailored to students' needs, AR applications create a more optimal learning experience. Furthermore, the use of AR helps reduce the cognitive load experienced by students during learning activities, as the material is presented visually and interactively. In a case study in an art school environment, AR was also proven to significantly improve students' independent reasoning, critical thinking, and creativity. Other studies comparing learning using Augmented Reality (AR) and without AR have shown that AR provides positive benefits, such as increased understanding of the material, strengthening spatial-based learning structures, developing language associations, and long-term information retention (Hussain et al., 2021). Meanwhile, another study described active engagement between teachers and students in the use of AR simulations, finding that this technology can create a hybrid learning environment. This environment supports the development of critical thinking processes more effectively in learning activities (Parmaxi & Demetriou, 2020).

Furthermore, several other studies have also proven that AR-based media has a positive impact on improving student learning outcomes. Research by (Sari et al., 2023), for example, showed that AR-based flashcards developed for mathematics learning significantly improved students' cognitive learning outcomes. Another study by Akmal and Nurjanah (2024) which examined the influence of AR on vocabulary learning, also concluded that the use of AR had a positive impact on student motivation and comprehension in primary English learning. Similar findings were presented by Zhang et al. (2025) stated that AR can improve vocabulary acquisition and retention more effectively than traditional learning methods.

In Indonesia, the use of AR technology in English learning at the primary school level is still very limited. Rosyidah and Anugerahwati (Rosyidah & Anugerahwati, 2024) identified limited technological infrastructure, lack of teacher training, and a lack of contextual AR content as the main factors contributing to the low adoption of AR in English learning. This results in a gap between the technology's potential and actual practice. However, within the framework of 21st-Century Education, technology integration in learning is not merely a complement but a necessity to improve the quality, accessibility, and meaningfulness of student learning (Putri et al., 2024).

Although various studies have shown that Augmented Reality (AR) can improve motivation, comprehension, and vocabulary retention, most of these studies still focus on learner contexts outside Indonesia or at the secondary and tertiary levels. Furthermore, research related to AR in language learning in elementary schools is generally limited to small-scale experiments without integration with the national curriculum. In the

Indonesian context, particularly in the implementation of the Independent Curriculum (Kurikulum Merdeka), there are still very few AR media specifically designed to meet the cognitive characteristics of elementary school students and the needs of English vocabulary learning. Furthermore, R&D research that combines expert validation, teacher practicality, student responses, and effectiveness measurement through multi-cycle learning is still rare. Thus, there is a research gap in the lack of flashcard-based AR media that have been systematically developed and comprehensively tested to improve vocabulary mastery in Indonesian elementary school students through a research and development approach. Within this framework, this research was developed to address the need for innovative, contextual, and relevant vocabulary learning media that meet the needs and characteristics of primary school students. This research aims to develop Augmented Reality (AR)-based flashcard media that can improve primary school students' English vocabulary mastery. This media is designed to not only present words and images, but also provide sound elements, animations, and interactive learning experiences that support active student engagement. To ensure the quality of the developed media, this research uses the ADDIE development model, which consists of five stages: analysis, design, development, implementation, and evaluation (Branch, 2009).

This research is expected to provide theoretical and practical contributions to the world of education, particularly in the development of English language learning media at the primary school level. Theoretically, this research expands the study on the effectiveness of AR in vocabulary learning and provides a basis for developing technology-based media for early childhood. Practically, the media resulting from this research can be an innovative learning alternative that English teachers can use to improve the quality of teaching and student learning outcomes. Furthermore, this research also has the potential to serve as a reference for curriculum developers and policymakers in developing technology-based English learning programs that are tailored to local needs.

Thus, the study aimed to prove the research questions: 1) How does AR Flashcard can be implemented as the media to teach vocabularies? 2) How the teachers' and students' perspectives on using AR Flashcard as the learning media? 3) Is there an effectiveness of using AR Flashcard to improve students' vocabulary mastery?

METHOD

This study uses 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. The ADDIE model stages are based on (Tegeh, 2014). This model is widely used in the development of learning tools because it is systematic and flexible (Branch, 2009). Each stage is implemented in a structured manner to ensure the development and effectiveness of Augmented Reality (AR)-based Flash Card learning media for fifth-grade students.

The first stage, Analysis, focuses on identifying needs through a comprehensive evaluation of students' reading challenges. This process includes an analysis of existing teaching materials, the classroom environment, and the learning aids used by teachers. According to Molenda (2003), the analysis stage in the ADDIE model aims to understand learning gaps and user needs as a basis for developing appropriate learning solutions. This information is crucial for formulating specific needs in AR media development.

Before the designing phase, the pretest is given to measure their vocabulary mastery without implementing the AR Flashcards in the learning process. It also aims to find out the students' needs while using the AR Flashcards as the media to learn vocabularies.

The Design phase involves gathering relevant materials and creating a detailed blueprint for the learning media. In this phase, special attention is paid to tailoring the design to the cognitive abilities of fifth-grade students through the implementation of

interactive elements and engaging visual features. In line with Reigeluth (1999), effective learning design must consider learner characteristics, learning objectives, and appropriate delivery strategies.

The Development phase involves creating an initial prototype of AR-based Flash Card media. This prototype is then rigorously validated by experts in content, pedagogy, and media technology. Instrument validation is conducted using an assessment rubric covering three main aspects: content accuracy, pedagogical suitability, and media design quality. According to Akker (1999) expert validation is crucial in the development of learning products to ensure the product's quality and feasibility before implementation. Each of these aspects is assessed using a numerical scale and accompanied by quantitative feedback for product refinement. During this process, the students are also given the test (Cycle 1 and Cycle2) to measure their vocabulary mastery during implementing AR Flashcards in the developing phase.

Following the validation process, the research proceeded to the Implementation phase, where the media was piloted on 25 fifth-grade students at an primary school in Bantul. This phase aimed to observe student interactions with the media and gather feedback regarding the media's effectiveness and appeal. According to Gall et al. (2007), initial field trials are crucial in identifying issues with the use and effectiveness of learning products in real-world contexts. The final phase, Evaluation, involved analyzing data from the pilot trials and expert validation to assess the product's feasibility. This evaluation was both formative and summative, aiming to address weaknesses and ensure the media was ready for use in learning (Tessmer, 1993). To give the evidence in the final evaluation, the pretest has given to the students. It aims to measure their final understanding on vocabulary mastery after implementing the AR Flashcards. This evaluation process ensured that media development was iterative and continuously refined to meet the needs of students and teachers.

The study involved 25 fifth-grade students from a public elementary school in Bantul, Yogyakarta. English is taught as supplementary content twice a week for 35 minutes. In general, students' English skills are at a beginner level, characterized by limited vocabulary and minimal exposure to the language outside of the classroom. The school has a basic digital infrastructure that allows for the interchangeable use of Android devices during AR-based learning.

The research instruments used consisted of a validation questionnaire from material experts and media experts, a teacher response questionnaire, a student response questionnaire, and a vocabulary mastery test. The expert validation questionnaire was used to assess the appropriateness of the content, pedagogical suitability, and the quality of the media's appearance and function. The teacher and student response questionnaires were used to measure the level of practicality, ease of use, motivation, and engagement during learning with AR Flashcards. The vocabulary mastery test in the form of a pretest, a test for each cycle, and a posttest was used to measure the development and improvement of students' vocabulary mastery throughout the implementation process.

Data collection in this study was conducted through the instruments, questionnaires and test. The questionnaires provided information regarding the media's effectiveness and ease. It’s also used to obtain quantitative data based on expert validation and the results of student and teacher responses. Quantitative analysis was used to process validation scores from the content, learning methodology, and media design aspects. Furthermore, the students’ pretest and posttest are also used to measure the AR flashcards effectiveness. The data analysis in this study was conducted using a quantitative approach. Data from the expert validation questionnaire were analyzed by calculating the average score and the feasibility percentage to determine the media validity category. Data from the teacher and student response questionnaires were analyzed by calculating the average

score for each indicator to obtain the media's practicality and effectiveness categories. Vocabulary mastery test data were analyzed by comparing pretest scores, each cycle's scores, and posttest scores to see the improvement in students' abilities. The completion category was determined based on the Minimum Completion Criteria (KKM), which is 75, set by the school, and the percentage of students achieving completion was calculated at each stage. In addition, the improvement in learning outcomes was calculated using the average difference (gain score) between the initial and final scores to demonstrate the effectiveness of using AR Flashcards in improving students' vocabulary mastery.

RESULTS AND DISCUSSION

Results

This section presents the results of the development and implementation process of Augmented Reality (AR)-based flashcard learning media aimed at improving English vocabulary mastery of 5th grade primary school students. The research findings are divided into five main aspects, namely: (1) validation by material experts, (2) validation by media experts, (3) teacher responses, (4) student responses, and (5) vocabulary test results before and after using the media. Data were obtained through questionnaires and the scores from pre-tests and post-tests, which were then analyzed descriptively.

Table 1. Content Expert Validity Results

No	Indicators	Rating				
		1	2	3	4	5
1.	Alignment of learning material with the dimensions, elements and purposes					✓
2.	Accuracy of the material appropriate					✓
3.	Relevance and timeliness of the material in the context of students' daily life					✓
4.	The material stimulates students' curiosity				✓	
5.	Conceptual accuracy of the content delivered				✓	
6.	Sequential and structured delivery of material					✓
7.	Presence of assessment indicators that are appropriate for students					✓
8.	Appropriateness and clarity of images used to support understanding					✓
9.	Material is aligned with students' cognitive development at Phase C				✓	
10.	The language used is easy to understand for primary students					✓
11.	The sentences are clear and concise					✓
12.	The presentation supports students' effective learning					✓
13.	The structure of the material is easy to follow				✓	
14.	Logical flow and coherence of the content				✓	
	Total	65				
	Percentage	93%				
	Scale	Highly Effective				

Expert validation results for Augmented Reality (AR) flashcard-based learning media indicate that the developed material is highly suitable for use in the learning of 5th-grade primary school students in Phase C of the Independent Curriculum. Based on an assessment of 14 indicators covering content, instructional design, and suitability to student characteristics, a total score of 65 was obtained out of a maximum score of 70, with a percentage of 93%. This percentage indicates that the media is included in the "Highly Effective" category. The assessment shows that the material is in accordance with learning objectives, accurate in content presentation, and relevant to the students' life context. Visualization through AR is also considered interesting and able to increase learning motivation.

The language used is easy for primary school students to understand, with concise and clear sentences. The presentation of the material is also structured coherently, has an easy-to-follow structure, and flows logically. The 3D images and animations included in the flashcards are deemed appropriate in aiding conceptual understanding. This material is also considered appropriate for the cognitive developmental stage of fifth-grade students, who are beginning to be able to think logically and comprehend complex visual information. Furthermore, the material encourages active student engagement, such as discussions with peers, and helps students remember and understand the vocabulary learned. Based on these validation results, it can be concluded that AR flashcard-based learning media is not only technologically innovative but also pedagogically effective and ready for implementation in primary school learning.

Table 2. Media Expert Validity Results

Evaluation Aspects	Interval	Results	Category
Usefulness and Function	$3.5 \leq V \leq 4$	4	Valid
Media Display	$3.5 \leq V \leq 4$	4	Valid
Average	$3.5 \leq V \leq 4$	4	Valid

Validation results by media experts on the development of AR flashcard-based learning media indicate that the media is valid and suitable for use in learning. Two aspects were evaluated: Usefulness and Function and Media Display, each of which received an average score of 4.00 within a validity interval of $3.5 \leq V \leq 4$, categorized as Valid. This indicates that, in terms of usability, the media is considered to provide tangible benefits in supporting the learning process, both in aiding material understanding, increasing student engagement, and supporting the achievement of learning objectives.

Regarding media display, the assessment results also indicated that the AR flashcard visualizations were deemed attractive, informative, and appropriate for the characteristics of primary school students. The visual design, color selection, font size, and presentation of animated elements were deemed to meet aesthetic and pedagogical principles, thus facilitating student access and comprehension of the material.

The overall average score for both aspects was also 4.00, confirming that the media meets the appropriateness standards in terms of design and function. Thus, the results of this validation provide a strong basis that the AR flashcards learning media is not only technologically innovative, but also has the appropriate display quality and usability for use in the learning of 5th grade primary school students (Phase C).

Table 3. Teacher Response Results

Evaluation Aspects	Interval	Results	Category
Preparation	3.25 – 4.0	3.5	Good Practical
Usage	3.25 – 4.0	4	Excellent Practical
Management	3.25 – 4.0	4	Excellent Practical
Average	3.25 – 4.0	3.8	Excellent Practical

Teacher responses indicated that AR flashcards were considered highly practical and easy to use in learning. Assessments were conducted across three main aspects: Preparation, Usage, and Management. The Usage and Management aspect received a maximum score of 4.00, falling within the "Excellent Practical" category. This indicates that teachers considered the media highly effective and efficient when used in the classroom, and easy to manage during the learning process.

Meanwhile, for the Preparation aspect, teachers gave a score of 3.5, falling within the "Good Practical" category. This score indicates that while preparation for using AR

flashcards was considered good, there is still a potential need for simplification or additional guidance to make it easier for teachers to understand and use independently, particularly in the context of integrating technology into teaching and learning activities at the primary school level.

Overall, the average score was 3.8, falling within the "Excellent Practical" category. These results indicate that teachers strongly welcome the use of AR flashcards as a learning medium. This media is considered capable of increasing the effectiveness of the teaching and learning process and is relevant to the needs and characteristics of fifth-grade primary school students. This positive response also indicates that the developed media can be widely implemented in classroom learning, with adequate teacher preparation.

Table 4. Students Response Results

No	Indicators	Total Score				∑
		1	2	3	4	
1.	I enjoy learning with AR flashcards.				25	4.0
2.	This is my first-time using AR flashcards in learning.				25	4.0
3.	The language used in the AR flashcards is difficult to understand		19	6		2.24
4.	AR flashcards make me want to discuss with my friends.			11	14	3.56
5.	The 3D images/animations in the AR flashcards are clear and easy to understand.			5	20	3.80
6.	The visual design is attractive (e.g., animation, font size, colors).			7	18	3.72
7.	Learning with AR flashcards is fun and not boring.			2	23	3.92
8.	AR flashcards are easy and practical to use.			12	13	3.52
9.	Learning English with AR flashcards makes me more active during class.				25	4.0
10.	AR flashcards help me understand and remember the material more easily.			3	22	3.88
Total						36.64
Percentage						36%
Category						Highly Effective

Student responses to the use of Augmented Reality (AR) flashcards as a learning medium indicate that this medium is highly effective in supporting English learning for fifth-grade primary school students (Phase C). The assessment was conducted on 10 indicators covering affective, cognitive, and visual aspects of the media. The total results showed an average score of 3.66 on a maximum scale of 4.00, categorized as "Highly Effective," reflecting a very positive response from students.

Three indicators received a perfect score (4.00): "I enjoy learning with AR flashcards," "This is my first-time using AR flashcards in learning," and "Learning English with AR flashcards makes me more active during class." These findings indicate that students not only enjoyed the AR learning experience but also became more motivated and active in participating in learning activities. This aligns with the characteristics of Phase C students, who tend to prefer visual, interactive, and hands-on learning.

Other indicators, such as "The 3D images/animations in the AR flashcards are clear and easy to understand" (3.80), "The visual design is attractive" (3.72), and "AR flashcards help me understand and remember the material more easily" (3.88), indicate that the visual design and animation aspects of the media are considered highly supportive of student understanding. This strengthens AR's position as a medium that is not only visually appealing but also capable of simplifying abstract concepts into more concrete and easily digestible concepts.

However, the indicator "The language used in the AR flashcards is difficult to understand" received the lowest score of 2.24, indicating that some students still have difficulty understanding the language used in the media. This is an important note: even though the visual display is optimal, simplification and adjustment of the language are essential to ensure the material is truly appropriate for the language proficiency level of primary school students.

These results indicate that the use of AR flashcards has great potential for application in English vocabulary learning at the primary school level. This medium is considered capable of creating a fun learning experience, encouraging active participation, and improving student comprehension and retention. 3D visualization support and media interactivity play an important role in bridging students' learning needs based on context, experience, and exploration, in accordance with the principles of the Independent Curriculum which emphasizes meaningful and student-centered learning.

Table 5. Comparison of Students Vocabulary Test Based on Pretest and Posttest Scores

Aspects	Pretest	Cycle 1	Cycle 2	Posttest
Mean	73	77	81	87

The comparison between students' pretest and posttest means is described based on the table 5. The data shows students' mean in the pretest is 73, while the posttest mean in the posttest is 87. It means that there is a significant improvement among the students' scores from the pretest to the posttest. Moreover, the improvement is also indicated based on the comparing between the mean scores in the Cycle 1 and Cycle 2. In the Cycle 1, students' mean score is 77, while in the Cycle 2 the students' mean scores is 81. It shows the students' vocabulary mastery has improved through the implementing AR Flashcards.

Table 6. Comparison of Students Vocabulary Test Before and After Implementing AR Flashcards

Aspects	Pre-Cycle	Cycle I	Cycle II	Cycle III
Mastery	f-10	f=14	f=19	f=23
	%=40%	%=56%	%=76%	%=92%
Not Mastery	f=15	f=11	f=6	f=2
	%=60%	%=44%	%=24%	%=18%

Table 6 presents the results of a comparison of students' English vocabulary mastery before and after the implementation of AR flashcards in three learning cycles. The data shows a significant increase in vocabulary mastery from the pre-cycle stage to cycle III. In the pre-cycle stage, only 10 students (40%) reached the "mastery" category, while 15 students (60%) remained in the "not mastered" category. This indicates that the majority of students had not adequately mastered basic English vocabulary before the treatment.

After the implementation of AR flashcards in cycle I, the number of students who mastered vocabulary increased to 14 (56%), while those who had not yet mastered it decreased to 11 (44%). This increase indicates that AR media began to have a positive impact on students' vocabulary comprehension. More significant progress occurred in cycle II, with 19 students (76%) reaching the mastery category and only 6 students (24%) remaining unmastered. This indicates that the AR flashcard intervention is increasingly effective in helping students understand and remember vocabulary. In cycle III, the best results were achieved, with 23 students (92%) declared to have mastered the vocabulary, and only 2 students (8%) not yet achieving mastery. These results reflect the successful use of AR flashcards as a learning medium, which can gradually and consistently improve

student learning outcomes. Overall, these data indicate that the use of AR flashcards in English vocabulary learning has a real positive impact on improving student learning outcomes. This medium is not only visually engaging and interactive, but also increases student engagement and understanding, effectively helping them achieve higher levels of mastery over time. Thus, AR flashcards have proven to be an innovative learning medium worthy of integration into primary school learning.

Discussion

The findings of this study demonstrate that Augmented Reality (AR)-based flashcards significantly improved primary school students' English vocabulary mastery, as indicated by expert validation, teacher and student responses, and substantial increases in test scores across learning cycles. These results align with a growing body of research endorsing AR as an effective tool for enhancing engagement, comprehension, and retention in language learning environments. The high feasibility score from material experts (93%) and the perfect validity score from media experts confirm that the AR flashcards were pedagogically sound and technologically functional. This reinforces the idea that learning media combining visual, auditory, and interactive elements supports young learners' comprehension and motivation, especially during the concrete operational stage when children rely heavily on sensory input and contextual cues to construct meaning .

The improvement in vocabulary mastery—from 40% of students achieving mastery in the pre-cycle to 92% in the final cycle—reflects not only the quality of the AR media but also the suitability of AR tools for young learners. These findings corroborate the results of Zhang et al. (2025), who found that AR enhances vocabulary learning effectiveness and supports long-term retention better than traditional flashcards. Similarly, Akmal and Nurjanah (2024) reported that AR increases students' motivation and comprehension in primary English learning, suggesting that the benefits observed in this study stem from AR's capacity to provide multisensory input that facilitates deeper cognitive processing. The interactive 3D visuals and animations embedded in the AR flashcards appear to help students connect new vocabulary to concrete representations, thereby reducing cognitive load and promoting more meaningful learning, as also suggested by Xue and Wang (2021).

The positive response from students—reflected in high enjoyment (4.00), increased activeness (4.00), and improved recall (3.88)—provides strong support for AR as a tool that fosters learner engagement. These results are consistent with Madanipour and Cohrssen (2020), who found that AR in early childhood education increases student interest and supports exploration-based learning. The findings also reflect the principles of the Independent Curriculum (Kurikulum Merdeka), which emphasizes student-centered, contextual, and joyful learning experiences. Through AR, students not only encountered vocabulary items visually but also interacted with them actively, stimulating curiosity and encouraging peer discussion. Such interactive learning aligns with Parmaxi and Demetriou's (2020) observation that AR creates hybrid learning environments where students engage collaboratively and critically, making vocabulary learning more interactive and dynamic.

Teacher responses also revealed high practicality, particularly in the usage and management aspects, scoring a perfect 4.00. This suggests that AR flashcards offer ease of integration into classroom routines. However, teachers rated preparation slightly lower (3.5), reflecting a need for clearer guidelines or simplified procedures for first-time users. This is consistent with challenges outlined by Rosyidah and Anugerahwati (2024), who noted that limited teacher training is a major barrier to AR adoption in Indonesian classrooms. While AR offers rich pedagogical opportunities, its sustainability in learning

environments depends largely on educators' familiarity and confidence with the technology. Therefore, this study highlights the importance of providing teachers with appropriate training modules and technical support to ensure optimal use of AR tools.

One interesting finding relates to students' difficulty in understanding some of the language used in the flashcards, indicated by the lowest response score (2.24). This suggests that although AR media can enhance engagement and comprehension, linguistic complexity remains a crucial consideration. This aligns with Mahdi's (2024) conclusion that flashcards—digital or physical—must present vocabulary with simple, child-friendly language to prevent learner frustration and confusion. Thus, AR media developers must balance technological sophistication with linguistic accessibility to ensure that all learners, regardless of proficiency level, can benefit from the materials.

When viewed through the lens of cognitive theory, the success of AR flashcards in this study can be attributed to the dual coding theory, which states that verbal and visual information processed simultaneously enhances memory retention. The combination of 3D images, animations, and audio elements likely strengthened mental representations of vocabulary items, making them easier to recall. Additionally, the interactive nature of AR supports constructivist learning theory, where learners build knowledge actively through exploration and manipulation of stimuli. By merging these principles, AR flashcards maximize comprehension gains and maintain learner engagement.

From a practical perspective, the findings suggest several implications for language teaching in primary schools. First, AR-based flashcards can serve as an effective supplementary tool for reinforcing vocabulary learning, especially when exposure to English is limited to short weekly sessions, as was the case for the students in this study. The media encourages autonomous exploration, allowing students to review vocabulary beyond classroom boundaries if devices are available. Second, AR tools can help teachers address diverse learning styles by providing multimodal representations that cater to visual, auditory, and kinesthetic learners. This adaptability supports inclusive learning practices, ensuring that different types of learners can access content meaningfully.

Furthermore, the significant improvement across cycles illustrates the importance of sustained and iterative use of AR tools in vocabulary instruction. While students benefited from initial exposure, their vocabulary mastery improved progressively through repeated cycles of AR-assisted learning. This observation aligns with Sari et al. (2023), who noted that repeated interactions with AR media strengthen understanding and performance. Therefore, AR flashcards should not be viewed as one-time interventions but as components of ongoing teaching strategies.

CONCLUSION

The findings of this study lead to the conclusion that AR-based flashcards are effective, feasible, and practical learning media for improving primary school students' English vocabulary mastery. Validation from material experts showed a feasibility level of 93%, indicating that the content, structure, and language of the media are accurate, relevant, coherent, and appropriate to the cognitive characteristics of fifth-grade learners. Media experts also rated the design and functionality as valid, confirming that the visual and technical aspects support meaningful learning. These expert validations were reinforced by teachers' very positive responses, especially in terms of ease of use, classroom management, and alignment with instructional goals. Students likewise responded enthusiastically, reporting high enjoyment, increased activeness, and better understanding and recall when learning with AR flashcards, even though some still found parts of the language challenging.

In terms of learning outcomes, the study demonstrated a substantial and consistent increase in vocabulary mastery across three learning cycles, with mastery improving from

40% in the pre-cycle to 92% in the final cycle. The gradual rise in mean scores from the pretest through each cycle to the posttest indicates that repeated and systematic use of AR flashcards can significantly strengthen vocabulary acquisition and retention. These results confirm that integrating AR technology into vocabulary instruction can transform learning from a passive, text-based activity into an interactive, student-centered experience that aligns with the principles of the Independent Curriculum. Overall, the study concludes that AR-based flashcards offer a promising and innovative solution for enhancing vocabulary learning in Indonesian primary schools and can serve as a valuable reference for teachers, media developers, and policymakers seeking to integrate educational technology in early English language education.

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