

DEVELOPING AUGMENTED REALITY FLASHCARDS TO ENHANCE VOCABULARY LEARNING AMONG YOUNG LEARNERS

Ni Wayan Satri Adnyani, Ida Bagus Gde Phalaguna

*satri.adnyani@uhnsugriwa.ac.id

Universitas Hindu Negeri I Gusti Bagus Sugriwa Denpasar, Indonesia

ABSTRACT

Vocabulary learning plays a crucial role in young learners' English language development. However, traditional memorization techniques often fail to promote meaningful engagement and long-term retention. This study aimed to develop and evaluate Augmented Reality (AR) flashcards integrated with annotation features, an innovation designed to support personalized and multisensory vocabulary learning among young learners. The study employed the Research and Development (R&D) model consisting of the phases of design, development, review, revision, and implementation. To evaluate the developed product, quantitative and qualitative data were collected from 50 eight-year-old students in urban and rural elementary schools in Bali, Indonesia through vocabulary tests, classroom observations, interviews, and surveys. Quantitative findings revealed a significant improvement in learners' vocabulary achievement, with mean scores increasing from 56.22 to 76.62 ($p < .001$). Qualitative findings indicated that the integration of annotation with AR enhanced learners' engagement, encouraged active participation and personalized learning, and supported deeper vocabulary comprehension through multisensory interaction. Teachers also reported positive perceptions regarding the usability and pedagogical value of the AR flashcards, although limited device availability and teacher readiness remained practical challenges. These findings suggest that AR flashcards with annotation features provide an effective and engaging instructional tool for enhancing vocabulary learning among young learners.

Keywords: Annotation, Augmented Reality, Multisensory Learning, Vocabulary Learning, Young Learners

INTRODUCTION

Vocabulary plays an important role in young learners' English language development, serving as the basis of communication, cognitive growth, and academic success. Educator and educational researchers have known for years that vocabulary plays a pivotal role not only in helping students build and enhance their reading comprehension and writing ability but also in assisting them to construct their communicative ideas (Yanto, 2017). Children use vocabulary to express their thoughts, share emotions, and understand their surroundings. A rich vocabulary in early childhood strongly predicts later achievement in reading comprehension and writing (Jhonston, 2024). When young learners learn a wide range of words, they are better equipped to understand texts and communicate effectively, supporting their long – term literacy development and overall language proficiency.

*Corresponding author

Ni Wayan Satri Adnyani

Email: satri.adnyani@uhnsugriwa.ac.id

Recognizing the importance of vocabulary mastery, it is advisable to introduce new vocabulary to students early on (Palupi, 2024).

However, vocabulary mastery is not only about memorizing words, but it is also about how it is taught. In many English language classrooms, traditional methods such as rote memorization and drilling remain dominant (Chai et.al., 2021). These approaches often fail to provide meaningful learning experiences or contextual understanding. Learners may be able recall words temporarily but struggle to use them appropriately in real – life communication (Soltikova, 2023). Furthermore, such repetitive and passive methods tend to disengage young learners, reducing motivation and long-term retention.

These challenges have particularly happened in Indonesia, where English is taught from early at schools but is often taught through teacher-centered and textbook-based approaches (Daud, 2024). Because so many rural and under-resourced areas still lack access to interactive learning tools, many learners miss out on the chance to experience English in a more engaging and enjoyable way (Kemendikbudristek, 2022). Teachers always face large class sizes and a lack of multimedia resources, which makes it difficult to provide individual attention or incorporate multisensory learning experiences. It makes young learners often encounter English as a subject to memorize rather than a language to explore and use meaningfully (Daud, 2024; Zein et al., 2020). To overcome this problem, innovative strategies that support active, enjoyable, and context-rich learning are urgently needed.

One solution for this problem is using Augmented Reality (AR) technology. AR blends digital content with the real world and it allows young learners to interact with 3D visuals, animations and audio in real time. These immersive experiences make abstract vocabulary more tangible and comprehensible for young learners (Chen & Chan, 2019). Studies have shown that AR-based learning tools can enhance motivation, engagement, and retention by turning vocabulary practice into playful exploration (Ibrahim et al., 2018; O'g'li & Khurshidbek, 2024). Instead of relying solely on repetition, children can now visualize, hear, and manipulate words in interactive ways that promote deeper understanding. Such multisensory and experiential learning aligns well with young learners' developmental needs, as they learn best through active engagement and discovery.

Despite the benefits of AR for vocabulary learning, most existing AR applications primarily focus on multimedia features such as 3D visualization, animation, and audio pronunciation to improve learners' engagement and vocabulary retention (Ibrahim et al., 2018; Chen & Chan, 2019; Hung & Yeh, 2023). However, few studies have incorporated annotation features that allow learners to actively label, highlight, or record notes while interacting with vocabulary items. Such activities promote deeper cognitive processing by encouraging learners to connect new vocabulary with prior knowledge. To address this gap, the present study develops AR flashcards that integrate annotation features, enabling learners to engage in more personalized and meaningful vocabulary learning.

Therefore, this study focuses on developing and evaluating Augmented Reality Flashcards with Annotation Features to enhance vocabulary learning among young learners. The integration of annotation with AR aims to provide not only visual and auditory stimulation but also opportunities for learners to personalize their learning experience and engage more deeply with vocabulary.

Based on Dual Coding Theory (Paivio, 1986) and Constructivist Learning Theory, the AR flashcards were designed to combine visual, auditory, and interactive elements to strengthen vocabulary learning. According to Dual Coding Theory, presenting words through 3D images and audio pronunciation enables learners to process information through both verbal and visual channels, enhancing retention. Constructivist Learning Theory informed the integration of the annotation feature, which allows learners to label images and write short notes, encouraging them to actively construct meaning by connecting new vocabulary with their prior knowledge. Together, these features promote more meaningful and lasting vocabulary acquisition. Based on this background, the study addresses the following research questions:

1. What key features and design principles should be incorporated into AR flashcards to effectively support young learners' vocabulary learning?
2. To what extent do AR flashcards improve young learners' vocabulary retention and recall compared to traditional teaching methods?
3. How do the multisensory elements of AR flashcards (e.g., visuals, audio, animations, and annotations) influence learners' engagement and motivation in vocabulary learning?

By answering these questions, this study contributes to the growing body of research on educational technology integration in early language learning. It provides empirical evidence on how AR tools with annotation features can bridge the gap between engagement and comprehension, offering both theoretical insights and practical implications for teachers seeking to create interactive, children-centred English learning environments.

METHODS

This study employed a Research and Development (R&D) design adapted from Borg and Gall (1983) to develop and evaluate Augmented Reality (AR) flashcards with annotation features for enhancing young learners' vocabulary learning. The R&D approach was selected because the study focused not only on measuring learning outcomes but also on systematically designing, developing, validating, revising, and implementing an educational product. The development process consisted of five major phases: (1) needs analysis and design, (2) product development, (3) expert review, (4) product revision, and (5) classroom implementation. To evaluate the effectiveness and usability of the developed product, both quantitative and qualitative data were collected through vocabulary tests, classroom observations, interviews, and surveys.

In addition, the development of the AR flashcards followed five sequential phases adapted from Borg and Gall (1983).

Phase 1: Needs Analysis and Design

The study began with a needs analysis involving English teachers and educational technology experts. Questionnaires and interviews were conducted to identify learners' vocabulary difficulties, desirable instructional features, and classroom needs. In addition, the Grade 2 English curriculum was analyzed to ensure that the selected vocabulary items were age-appropriate and aligned with curriculum objectives. The findings indicated that teachers required interactive learning media incorporating 3D visualization, audio pronunciation, and annotation features to promote active learning.

Phase 2: Product Development

Based on the needs analysis, the prototype of the AR flashcards was developed using Assemblr EDU. The flashcards covered familiar vocabulary themes, including zoo animals, farm animals, fruits, vegetables, and occupations. Each flashcard displayed a marker image that activated a three-dimensional object, accompanied by pronunciation audio and an annotation feature that allowed learners to label images, highlight information, or write short notes. The interface was designed with child-friendly navigation, bright colors, and simple icons to facilitate young learners' interaction with the application.

Phase 3: Expert Review

The prototype was evaluated by three experts in English education and two experienced elementary school teachers. They assessed the flashcards in terms of content relevance, usability, interactivity, and pedagogical suitability using structured review forms and semi-structured interviews. Their feedback provided recommendations for improving the instructional quality and usability of the product.

Phase 4: Product Revision

Based on the reviewers' feedback, several improvements were made to the prototype. These revisions included simplifying the user interface, improving image quality, refining the annotation function, enlarging interface icons, and enhancing audio pronunciation. The revised product was then prepared for classroom implementation.

Phase 5: Classroom Implementation

The final version of the AR flashcards was implemented during four classroom sessions involving young learners from two elementary schools. Before the intervention, students completed a vocabulary pre-test. During the implementation, learners used smartphones and tablets under teacher supervision while classroom observations were conducted to document their engagement and participation. After the intervention, a post-test, interviews, and perception surveys were administered to evaluate vocabulary improvement, learner engagement, and user satisfaction.

Furthermore, the participants consisted of 50 eight-year-old students enrolled in early English classes at two elementary schools in Klungkung, Bali, namely SD Negeri 1 Semarapura Tengah (urban school) and SD Negeri 2 Bungbungan (rural school). Each school contributed 25 students, allowing the study to examine the implementation of the AR flashcards in different educational contexts. Participants were selected based on the following criteria: (1) being eight years old, (2) enrolled in early English education, (3) possessing basic reading ability, and (4) obtaining parental or guardian consent. Learners with significant visual or hearing impairments were excluded because the AR flashcards relied heavily on visual and auditory interaction. In addition, three English education experts and two experienced elementary school teachers participated as expert reviewers during the product validation stage.

To ensure comprehensive data collection throughout the product development and evaluation process, several research instruments were employed, as presented in Table 1.

Table 1. Research Instruments

Instrument	Purpose
Needs Analysis Questionnaire	Identify classroom needs and desired learning features
Expert Interview Guide	Collect expert recommendations for product design
Content Analysis Checklist	Ensure curriculum alignment
Expert Review Form	Evaluate usability, interactivity, and pedagogical quality
Pre-test and Post-test	Measure vocabulary mastery
Observation Checklist	Record learners' engagement and participation
Feedback Survey	Explore teachers' and learners' perceptions

Quantitative and qualitative data were analyzed separately and integrated during the interpretation stage. Quantitative data obtained from the pre-test and post-test were analyzed using descriptive statistics, including mean scores, standard deviations, and gain scores. A paired-samples *t*-test was conducted to determine whether the differences between pre-test and post-test scores were statistically significant, while Cohen's *d* was calculated to measure the magnitude of the treatment effect. The normality of the data distribution was examined using the Shapiro–Wilk test prior to conducting the parametric analysis. All statistical analyses were performed using SPSS.

Qualitative data collected through classroom observations, interviews, and surveys were analyzed using Braun and Clarke's (2006) thematic analysis. The analysis involved coding recurring patterns, grouping codes into themes, and interpreting the findings in relation to the research objectives. To enhance reliability, two researchers independently coded part of the dataset before reaching consensus on the final themes.

The quantitative and qualitative findings were integrated during the interpretation stage to provide a comprehensive evaluation of the developed AR flashcards. Improvements in vocabulary achievement were interpreted alongside learners' engagement, motivation, and teachers' perceptions, enabling the effectiveness of the product to be examined from multiple perspectives.

FINDINGS AND DISCUSSION

Need Analysis

The needs analysis was conducted to identify learners' vocabulary learning needs and teachers' expectations regarding technology-supported instruction. Data collected through teacher questionnaires and interviews revealed three major challenges in teaching English vocabulary. First, teachers reported that many young learners had difficulty retaining newly learned vocabulary. Second, conventional instructional media, such as printed flashcards and textbooks, were considered insufficient to sustain learners' interest and engagement. Third, both urban and rural schools experienced limited access to interactive digital learning resources, making it difficult to provide meaningful and engaging vocabulary instruction.

Despite differences in school settings, teachers shared similar expectations regarding the characteristics of an effective learning medium. They emphasized the importance of instructional tools that are interactive, easy to operate, compatible with smartphones, and aligned with the elementary English curriculum. Educational technology experts further recommended integrating annotation features that allow learners to label, highlight, or add short notes to vocabulary items. According to the experts, these features could encourage active participation and deeper cognitive engagement during vocabulary learning. The findings of the needs analysis therefore served as the foundation for designing the AR flashcards with annotation features.

Product Development

Product Features

Based on the findings of the needs analysis, the AR flashcards were developed to support vocabulary learning through multisensory and interactive experiences. The product was designed around five vocabulary themes drawn from the Grade 2 English curriculum, namely zoo animals, farm animals, fruits, vegetables, and occupations. Using Assemblr EDU, each flashcard was equipped with a marker image that activated a three-dimensional object, accompanied by word spelling, audio pronunciation, and an annotation feature that enabled learners to label images, highlight important information, or write short notes. To ensure ease of use for young learners, the application was designed with a child-friendly interface featuring simple navigation, bright colors, and interactive icons. These features were intended to provide engaging vocabulary learning while encouraging learners to actively interact with the learning materials.

Expert Validation

The prototype was evaluated by four experts, comprising two English education lecturers and two instructional media specialists, who assessed the product in terms of content relevance, usability, interactivity, and aesthetic quality. The overall validation score

reached 90.5%, indicating that the AR flashcards were highly feasible for classroom implementation. Specifically, content relevance received a score of 93%, confirming that the selected vocabulary was appropriate for the target learners. Usability was rated at 88%, indicating that the application was easy to operate, while interactivity and aesthetic quality received scores of 91% and 90%, respectively, demonstrating that the multimedia features and visual design effectively supported vocabulary learning.

Product Revision

Following the expert evaluation, several revisions were made to improve the quality of the product before classroom implementation. The revisions included simplifying the home interface, improving pronunciation audio, enlarging the annotation icon, enhancing image quality, and refining the annotation function to make it more accessible for young learners. After these improvements were completed, the revised AR flashcards were considered suitable for classroom use and proceeded to the implementation stage.

Product Implementation

Pretest–Posttest Results

The effectiveness of the developed AR flashcards was evaluated through a pre-test and post-test administered to 50 young learners. The vocabulary assessment consisted of 20 multiple-choice items measuring word recognition, spelling, and meaning. As presented in Figure 1, the mean pre-test score was 56.22 (SD = 8.73), which increased to 76.62 (SD = 6.91) in the post-test, representing a mean gain of 20.4 points. A paired-samples *t*-test indicated that the improvement was statistically significant, $t(49) = 15.74$, $p < 0.001$, with a large effect size (Cohen's $d = 1.83$). The improvement was observed in both urban and rural schools, suggesting that the developed AR flashcards effectively supported vocabulary learning across different educational settings. The results of the pre-test and post-test can be seen in the following figure.

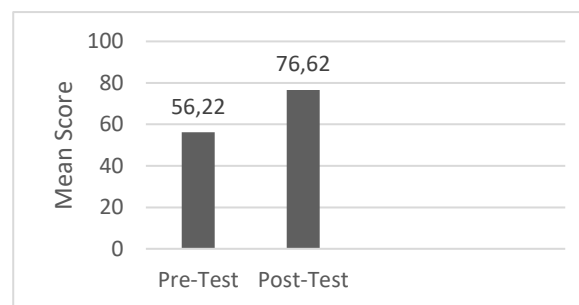


Figure 1. Pre- and Post-Test Results

Observation Results

Classroom observations were conducted during the four implementation sessions to examine learners' engagement and interaction while using the AR flashcards. Three consistent patterns were identified throughout the implementation. First, learners actively explored the learning materials by scanning flashcards, manipulating the three-dimensional objects, and relating them to real-life objects. Second, collaborative learning frequently occurred as learners assisted one another with pronunciation, exchanged annotations, and completed learning tasks together. Third, learners demonstrated positive emotional responses, including curiosity, enthusiasm, and excitement when interacting with the animated vocabulary items. Teachers also observed that learners maintained their attention longer than during conventional vocabulary lessons and that previously passive students became more willing to participate in classroom activities.

Survey Results

Questionnaire responses collected after the implementation indicated highly positive perceptions of the developed AR flashcards from both learners and teachers. Among the learners, 92% agreed that the AR flashcards made vocabulary learning more enjoyable. They particularly appreciated the three-dimensional objects, pronunciation audio, and annotation feature, which they believed helped them remember vocabulary more easily. Teachers also evaluated the product positively, highlighting three main advantages: increased learner motivation, ease of classroom integration, and flexibility for supporting various instructional activities, including vocabulary games, quizzes, and storytelling. Nevertheless, teachers noted two practical challenges during implementation, namely the need for a stable internet connection during the initial setup and limited device availability in some rural classrooms.

Interview Results

The interview findings further supported the survey and observation results. Learners reported that the combination of visual, auditory, and interactive features made vocabulary learning more interesting and enjoyable. Several learners explained that the annotation feature helped them remember new words by allowing them to write notes and connect vocabulary with their own experiences. Teachers similarly reported that the annotation function encouraged learners to participate more actively and reflect on vocabulary learning by constructing simple sentences related to their daily lives. Overall, the interviews indicated that the developed AR flashcards not only enhanced learners' engagement but also promoted more active participation throughout the learning process.

AR Flashcards Enhanced Vocabulary Learning

The findings demonstrate that the developed AR flashcards effectively enhanced young learners' vocabulary acquisition. The significant improvement in learners' vocabulary scores indicates that integrating three-dimensional visualization, audio pronunciation, and interactive learning activities created a more effective learning environment than conventional vocabulary instruction. Rather than relying solely on memorization, learners interacted with vocabulary through multiple sensory channels, enabling them to develop richer mental representations of new words.

These findings support Dual Coding Theory (Paivio, 1986), which proposes that information presented through both verbal and visual channels is more effectively processed and retained in memory. The integration of three-dimensional images with pronunciation audio enabled learners to associate vocabulary with concrete visual representations, thereby strengthening word recognition and recall. This finding is consistent with previous studies reporting that AR enhances vocabulary learning by increasing learners' motivation, attention, and retention through immersive multimedia experiences (Ibrahim et al., 2018; Chen & Chan, 2019; Hung & Yeh, 2023).

Annotation Features Promoted Active Knowledge Construction

Beyond the multimedia capabilities commonly found in AR applications, the present study demonstrates the value of integrating annotation features into vocabulary learning. The interview and observation findings showed that learners actively labelled images, recorded short notes, and related new vocabulary to their own experiences during learning activities. These interactions suggest that learners were not merely receiving information but were actively constructing vocabulary knowledge.

This finding reflects the principles of Constructivist Learning Theory, which emphasizes that meaningful learning occurs when learners actively connect new information with prior knowledge. By enabling learners to personalize vocabulary through annotation, the developed AR flashcards encouraged reflection, active participation, and deeper cognitive processing. While previous AR vocabulary studies have primarily

emphasized visualization and multimedia interaction (Ibrahim et al., 2018; Chen & Chan, 2019), the present study extends this line of research by demonstrating how learner-generated annotation can further support meaningful vocabulary learning.

Multisensory Learning Increased Engagement and Collaboration

The qualitative findings indicate that the developed AR flashcards created an engaging learning environment that encouraged active participation and collaboration. Classroom observations showed that learners enthusiastically explored the three-dimensional objects, exchanged ideas with peers, and participated more actively than during conventional vocabulary lessons. Teachers also reported that learners maintained their attention for longer periods and that previously passive students became more involved in classroom activities.

These findings suggest that multisensory learning experiences can increase learners' curiosity and willingness to interact with instructional materials. The combination of visual, auditory, and interactive elements provided immediate feedback and encouraged collaborative exploration, supporting Vygotsky's (1978) view that learning is socially constructed through interaction with others. The findings are also consistent with previous research demonstrating that AR promotes learner engagement by creating immersive and interactive learning experiences (Thees et al., 2020).

Implication and Contribution of the Developed AR Flashcards

This study contributes to the growing body of research on AR-assisted vocabulary learning by extending the functionality of conventional AR flashcards. The developed AR flashcards integrate annotation features that enable learners to label images, highlight information, and write short notes while interacting with vocabulary items. This additional functionality supports more personalized and active learning, complementing the multimedia affordances of AR. Furthermore, the study demonstrates that annotation can be effectively integrated into AR applications for young learners in authentic elementary school classrooms. The positive quantitative and qualitative findings suggest that combining multisensory interaction with learner-generated annotation offers a promising approach to supporting vocabulary learning, particularly in contexts where teachers seek engaging and learner-centered instructional media.

CONCLUSION

This study developed and evaluated Augmented Reality (AR) flashcards integrated with annotation features to enhance vocabulary learning among young learners. Following the Research and Development (R&D) model, the product was systematically designed, validated by experts, revised, and implemented in elementary school classrooms. The findings demonstrated that the developed AR flashcards were both pedagogically feasible and effective in improving learners' vocabulary achievement. Quantitative results showed a significant increase in vocabulary scores after the intervention, while qualitative findings indicated that the integration of three-dimensional visualization, audio pronunciation, and annotation features promoted learners' engagement, active participation, and personalized vocabulary learning.

The study extends previous research on AR-assisted vocabulary learning by integrating annotation features that enable learners to actively construct and personalize vocabulary knowledge rather than simply interact with multimedia content. This combination of multisensory learning and learner-generated annotation provides a more meaningful learning experience and offers an innovative contribution to technology-enhanced vocabulary instruction for young learners.

Despite these positive findings, the study was limited by its relatively small sample size, short implementation period, and implementation in only two elementary schools.

Future studies should examine the long-term effects of annotation-supported AR learning, involve more diverse educational settings, and explore additional interactive features to further enhance vocabulary development. Overall, the developed AR flashcards represent a promising instructional tool for supporting engaging, learner-centered, and meaningful vocabulary learning in primary English education.

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