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Bridging Visual Learning and Technology: Augmented Reality–Integrated Flashcards for English Vocabulary Instruction in Special Education

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ABSTRACT

Vocabulary learning is a key component of English as a Foreign Language (EFL) instruction, yet it remains challenging for students with special educational needs (SEN), particularly learners with autism spectrum disorder (ASD) and mild intellectual disability. This study developed and evaluated Augmented Reality (AR)-integrated flashcards as a visual, tangible, and multisensory instructional medium for English vocabulary learning in a special education classroom in Indonesia. Using a research and development design guided by the ADDIE framework, the study involved need analysis, media design, expert validation, classroom implementation and formative-summative evaluation. Data were collected through classroom observations, semi-structured teacher interviews, need analysis questionnaires, student response/observation records, and vocabulary pre- and post-tests. The expert validation indicated that the media was appropriate in terms of content, media design, and pedagogical suitability, while teacher feedback suggested that the flashcards were practical for classroom use. Students 'mean vocabulary score increased from 73.50 in the pre-test to 81.88 in the post-test; however, given the small number of participants (n=8), the effectiveness findings should be interpreted as preliminary and context-bound rather than generalizable. The findings suggest that AR-integrated flashcards may support vocabulary learning by combining dual visual-auditory input, repetition, tangible interaction, and teacher-guided reinforcement.

KEYWORDS:
Augmented reality;
Flashcards;
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Special education needs;
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Introduction

Inclusive education has become a fundamental principle in contemporary educational systems, emphasizing equal access to quality learning for all students, including those with special educational needs (SEN). This principle is strongly reflected in Indonesian educational policy, which promotes inclusive and special education services for learners with diverse

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cognitive, developmental, and social characteristics (Jimoh et al., 2024; Mulyadi, 2017; Somad et al., 2024). Among learners with SEN, children with autism spectrum disorder (ASD) and mild intellectual disability constitute a significant group that requires adaptive instructional approaches, particularly in language learning contexts (Klefbeck, 2023; Nemes, 2024).

English as a foreign language (EFL) is gradually being introduced in Indonesian special schools and inclusive classes. Vocabulary acquisition is a key component of EFL learning because vocabulary underpins the development of listening, speaking, reading, and writing (Nemes, 2024; Suharsih, 2022; Zudeta & Fitriani, 2023). For learners with SEN, however, vocabulary learning often requires more than repeated exposure to printed words. Children with ASD may experience difficulties in sustained attention, social communication, and abstract language comprehension, although many show strengths in visual processing and pattern recognition (Andreou et al., 2026). Learners with mild intellectual disability may also require simplified language input, concrete examples, structured routines, and repeated practice because of limitations in working memory and processing speed (Farid, 2025; Henry et al., 2022). These learning characteristics require instructional media that present vocabulary in concrete, visual, interactive, and developmentally appropriate forms.

Even in the face of these requirements, the teaching of English vocabulary in many special education contexts in Indonesia still relies on conventional teaching materials such as books, worksheets, and pictures (Crismeilani et al., 2025; Firdaus & Fitriani, 2025). While these materials are available, they usually lack the interactivity and multiple sensory input needed to maintain interest and support learning. Previous studies have reported that traditional instructional media frequently result in low learner motivation and limited vocabulary retention among SEN learners (Ariswanto & Muktamar, 2025; Azka et al., 2025; Gal & Ryder, 2025; Hidayat & Jannah, 2025; Hidayati & Amalia, 2025; Kainta & Rombot, 2020; Masitoh, 2022; Najakh, 2020). Consequently, there is a pressing need to innovate instructional media that are not only pedagogically sound but also responsive to the unique learning profiles of children with SEN.

Learning visually is another well-known method used in the classroom that benefits people with special needs. Using visual materials to convey information helps reduce cognitive load, increase understanding, and improve memorization by providing tangible, structured information (Hidayat & Jannah, 2025; Riadiyani et al., 2026). Several visual learning techniques have emerged over time. Flashcards are a classic teaching tool used to help students learn vocabulary. Flashcards make it easier for children to memorize new vocabulary by allowing them to repeat words and focus on the learning process. There is empirical evidence that using flashcards in vocabulary training can promote better vocabulary acquisition among learners with autism spectrum disorder and intellectual disabilities (Azizah et al., 2025; Sudiro et al., 2025). At the same time, conventional flashcards cannot engage learners and can limit interaction, especially in a technology-driven learning environment.

Advances in educational technology have created opportunities to enhance traditional visual learning tools through interactive digital media. One technology that has gained increasing attention in educational research is Augmented Reality (AR). AR allows digital elements, such as three-dimensional objects, animations, and audio, to be superimposed onto the real-world environment in real time through mobile devices (Khoirunnisa et al., 2023; Lian & Sunar, 2021; Lin et al., 2022; Mar'atullatifah & Ratnasari, 2023; Uiphanit et al., 2020). In education, AR has been shown to enhance engagement, motivation, and comprehension by transforming abstract or static representations into tangible, interactive experiences (Akçayır & Akçayır, 2017; Belda-Medina, 2022; Binhomran & Altalhab, 2021; Ersanli, 2023).

In language learning, Augmented Reality (AR) has shown considerable potential to support vocabulary acquisition. By providing multimodal input that combines visual, auditory, and kinesthetic elements, AR can facilitate deeper cognitive processing and improve vocabulary retention (Hersulastuti et al., 2025; Lee, 2022; Rohman et al., 2024). Recent studies have indicated that AR-based learning environments are particularly beneficial for learners with ASD, as they can support sustained attention, reduce distractions, and provide immediate visual feedback (Belda-Medina, 2022; Lee, 2022; Rohman et al., 2024). Furthermore, AR enables individualized pacing, allowing learners to interact with instructional content according to their own learning needs and abilities.

Nevertheless, many AR-based learning applications are fully digital and screen-based, which may not suit special education contexts. Children with SEN often benefit from tangible, hands-on learning materials that provide physical structure and teacher-guided interaction (Jalaluddin et al., 2020; Lin et al., 2022). Overreliance on screen-based applications may also pose practical challenges for classroom management, accessibility, and instructional control. Therefore, there is a need for instructional designs that integrate the strengths of digital technology with the familiarity and structure of traditional learning media.

Integrating AR with flashcards represents a promising pedagogical approach because it combines the structure of physical learning materials with the interactivity of digital content. Through this hybrid design, learners can scan printed flashcards using a mobile device to access three-dimensional visualizations, simple animations, and audio pronunciation of vocabulary items. The physical card helps maintain a concrete learning focus, while the AR layer adds immediate visual-auditory reinforcement. This design is particularly relevant for SEN learners because it supports vocabulary learning through repetition, multisensory input, and teacher-guided interaction without requiring learners to navigate a fully screen-based application (Martín-Del-pozo & Martín-Sánchez, 2022).

Theoretically, the use of AR-integrated flashcards can be understood through the lens of multimedia learning principles. Coordinated visual and auditory information can support dual-channel processing, while short labels, clear images, and repeated pronunciation cues may reduce unnecessary cognitive load for learners with limited working memory (Mayer & Fiorella, 2021). For learners with ASD, the stable visual marker of a flashcard may provide predictability and structure, whereas the AR object may attract attention and support meaning-making through concrete representation. Thus, the expected vocabulary gains are not merely due to technological novelty, but to the alignment between media affordances and learners' visual, repetitive, and multisensory learning needs.

Taken together, Multimedia Learning Theory, visual learning, inclusive education, and AR-supported learning provide a complementary explanation for the proposed instructional design. Multimedia Learning Theory explains how coordinated words, images, and pronunciation models can support dual-channel processing while minimizing unnecessary cognitive demands. Visual learning explains the value of concrete, stable representations for learners who show relative strengths in visual processing. Inclusive education emphasizes adapting the medium to learners' cognitive, attentional, and communicative characteristics rather than expecting learners to adjust to a standardized digital application. AR learning contributes interactivity, immediate visual-auditory reinforcement, and repeated engagement. In the present study, these perspectives are integrated through a hybrid mechanism in which the printed flashcard provides structure and predictability. In contrast, the AR layer provides animation, three-dimensional representation, and audio pronunciation. Therefore, the anticipated learning benefit is theoretically linked to the interaction of visual concreteness,

controlled multimodal input, repetition, and teacher-guided participation rather than to the novelty of AR alone.

Although AR in education has been widely explored, empirical research on AR-integrated flashcards for English vocabulary instruction among children with SEN remains limited, particularly in EFL contexts in developing countries (Howorth et al., 2019; Mar'atullatifah & Ratnasari, 2023). Most existing studies focus on mainstream learners or early childhood education, with relatively few addressing the specific cognitive and pedagogical needs of SEN learners. Moreover, many studies emphasize technological innovation without systematically examining instructional validity, practicality, and effectiveness in real classroom settings.

To address this gap, the present study focuses on designing and evaluating AR-integrated flashcards for English vocabulary instruction in a special education context. Guided by the ADDIE model, the study examines three aspects of instructional media quality: validity, practicality, and preliminary effectiveness. The research questions are: (1) To what extent are the AR-integrated flashcards valid in terms of content, media design, and pedagogical appropriateness for SEN learners? (2) To what extent are the AR-integrated flashcards practical for classroom use by teachers and learners? (3) To what extent do the AR-integrated flashcards show preliminary evidence of supporting English vocabulary acquisition among the participating learners?

This research is significant both theoretically and practically. Theoretically, it contributes to the literature on technology-enhanced language learning by explaining how AR, visual learning, and multimedia learning principles can be integrated for SEN learners in an EFL context. In practice, it offers a simple instructional alternative for teachers who need media that are visually engaging, concrete, repetitive, and manageable for special education classrooms. The study also provides a cautious empirical basis for further development and larger-scale testing of AR-supported vocabulary instruction.

Method

Research Design

This study employed a research and development (R&D) methodology to develop, validate, and evaluate AR-integrated flashcards for English vocabulary instruction in a special education context (McKim, 2017). The R&D approach was selected because the study not only produced an instructional product but also examined its quality, usability, and preliminary instructional impact in an authentic classroom setting. The development process was organized using the ADDIE framework, consisting of Analysis, Design, Development, Implementation, and Evaluation stages. In this revision, each ADDIE stage is reported as an operational research procedure rather than a general narrative description, including its data sources, participants, instruments, and outputs.

The ADDIE stages were operationalized as follows. In the analysis stage, the researchers identified learner characteristics, vocabulary-learning problems, available media, and classroom constraints through observations, teacher interviews, and a needs-analysis questionnaire. In the design stage, vocabulary content and card layout were designed. AR features and assessment indicators were mapped to the curriculum and learner profiles. In the Development stage, the prototype was produced and validated by three experts. During the implementation stage, teachers used the revised media in vocabulary lessons, while

researchers observed student interactions. In the evaluation stage, validation, practicality, qualitative feedback, and pre- and post-test data were analyzed to assess the media's quality and its preliminary contribution to learning.

Table 1. *Operationalization of ADDIE procedures*

ADDIE Stage	Data Source/ Activity	Instrument/ Documentation	Output Used for Revision
Analysis	Classroom observations, teacher interviews, need analysis questionnaire	Observation sheet, interview protocol, needs questionnaire	Learner profile, classroom constraints, required media features
Design	Mapping vocabulary content, layout, AR features, and learning steps	Curriculum review and media design blueprint	Prototype specification and storyboard
Development	Prototype production and expert validation	25-item validation sheets and open-ended expert comments	Revised content, visuals, audio AR responsiveness, and animation pacing
Implementation	Teacher-guided classroom trial with eight SEN learners	Implementation observation sheet and teacher notes	Evidence of practicality, student interaction, and classroom feasibility
Evaluation	Validation, practicality, qualitative feedback, vocabulary pre-/post-test analysis	Questionnaires, test scores, observation records	Validity, practicality, and preliminary effectiveness findings

Research Setting and Participants

The research was conducted in a special education school in Semarang, Indonesia. This setting was selected because it provides formal educational services for learners with autism spectrum disorder (ASD), particularly those diagnosed with autism spectrum disorder (ASD and mild intellectual disability. The participants included eight students aged 9-12 years who had been formally identified by the school as having ASD or mild intellectual disability, two special education teachers involved in English vocabulary instruction, and three expert validators: a media expert, a language education expert, and a special education expert.

Purposive sampling was used because the learners represented the intended end-users of the instructional media and the teachers had direct experience teaching vocabulary to SEN learners. The small number of student participants reflects the limited class size in the special education setting; therefore, the findings are interpreted as context-specific developmental evidence rather than evidence for broad generalization (Richey & Klein, 2009).

Analysis Stage

The analysis stage was conducted to generate empirical evidence about learners' needs and classroom conditions before the product was designed. Data were obtained from classroom observations, semi-structured interviews with teachers, and need-analysis questionnaires (El Shemy et al., 2024). Three classroom observations were conducted, each lasting approximately 40 minutes, during regular English vocabulary learning sessions. The observations focused on students' attention span, responses to visual materials, vocabulary recognition, pronunciation attempts, teacher prompting, and classroom management issues. The teacher interview protocol included questions about existing vocabulary-teaching practices, students' learning difficulties, available media, the feasibility of using mobile devices, and the expected features of the AR flashcards. The interviews were not audio-recorded to maintain teacher comfort and ethical standards; instead, the researchers

documented responses in written field notes during and after the interviews. The needs-analysis questionnaire asked teachers to rate the importance of visual clarity, repetition, audio support, simple instructions, and ease of media operation.

The analysis findings showed four main needs. First, students had difficulty maintaining attention when vocabulary was represented only through printed worksheets or oral explanation. Second, students required repeated exposure to vocabulary items and teacher modeling to support word recognition and pronunciation. Third, teachers reported limited access to interactive but manageable English learning media for SEN learners. Fourth, the instructional medium needed to be concrete, visually attractive, easy to operate, and compatible with short teacher-guided activities. These empirical findings became the basis for designing flashcards with clear images, limited text, audio pronunciation, simple AR objects, and repeated scanning activities.

Design Stage

Mayer and Fiorella (2021) discuss that the design stage involved planning content, visual layout, AR features, learning procedure, and assessment indicators. Vocabulary items were selected from concrete daily-life themes in the English curriculum used in the special education setting, prioritizing familiar food-related words that could be represented visually.

Each flashcard was designed to include a clear picture, the English word, the Indonesian meaning, a short contextual sentence, and a QR/AR marker. The design applied four principles: (1) minimal text to reduce unnecessary cognitive load, (2) high visual contrast to support attention, (3) audio pronunciation to reinforce articulation, and (4) repeated teacher-guided scanning to strengthen vocabulary retention. These principles are consistent with multimedia learning theory, which emphasizes coordinated visual and auditory input for learners with limited working memory capacity.

Development Stage

Mayer and Fiorella (2021) stated that during the development stage, the printed flashcards and AR objects were produced and integrated into a prototype. The prototype was reviewed by three validators using structured validation sheets. The validation instrument included 25 Likert-scale items covering content, media, and pedagogical validity, along with open-ended feedback sections. Content validity indicators included vocabulary appropriateness, thematic relevance, and linguistic accuracy. Media validity indicators included visual clarity, AR responsiveness, audio quality, and animation pacing. Pedagogical validity indicators included alignment with SEN learning principles, instructional simplicity, and repetition/ reinforcement. The experts' comments informed revision to the prototype, particularly improving audio clarity, slowing selected animations, and adjusting the contrast of several visual elements.

To strengthen the reporting of expert validation, item-level expert agreement was summarized using a Content Validity Index (CVI). Items rated 4 to 5 on the five-point scale were coded as relevant, while items rated below 4 were coded as less relevant. Based on the item-level validation sheets completed by three expert validators, the Item-level CVI (I-CVI) ranged from 0.67 to 1.00, while the scale-level CVI based on the average method (S-CVI/Ave) was 0.96. These results indicate that most items received strong expert judgment regarding their relevance to the instructional medium. Because only three experts were involved, the term "highly valid" is used cautiously to indicate expert-rated appropriateness rather than definitive psychometric validity.

Implementation Stage

The implementation stage involved applying the revised AR-integrated flashcards in real classroom vocabulary lessons. Before implementation, the participating teachers received brief training on how to scan the flashcards, activate the AR objects, play audio recordings of pronunciation, and guide students' responses. During the lessons, students interacted with the flashcards individually and in small teacher-guided groups.

The teacher introduced the vocabulary item, modeled pronunciation, guided students to scan the card, asked students to observe the AR object, and encouraged repetition through pointing, naming, matching, and pronunciation practice. The implementation took place over four vocabulary learning sessions, each lasting about 40 minutes. The sessions were conducted during regular English learning time to evaluate the media. The implementation was documented through classroom observation notes focusing on students' attention, engagement, prompting needs, and responses to the AR features (Azizah et al., 2025; El Shemy et al., 2024; Riadiyani et al., 2026; Sudiro et al., 2025).

Evaluation Stage

The evaluation stage assessed three aspects of the developed media: validity, practicality, and preliminary effectiveness (Azizah et al., 2025; Riadiyani et al., 2026; Sudiro et al., 2025). Formative evaluation was conducted through expert feedback and classroom observation during development and implementation. Summative evaluation was conducted after the classroom trial using teacher practicality questionnaires, student response/observation records, and vocabulary post-tests. The vocabulary test was administered as a pre-test before the implementation and as a post-test after the implementation. The test measured three dimensions: word recognition, meaning comprehension, and pronunciation accuracy. Teacher assistance was provided as needed to ensure students understood the instructions, but scoring focused on students' vocabulary performance.

The vocabulary test structure should be reported in detail to strengthen measurement quality. The test consisted of 20 vocabulary items covering three dimensions of vocabulary mastery: word recognition, meaning comprehension, and pronunciation accuracy. The word recognition session consisted of eight items in which students were asked to identify the correct English vocabulary item based on visual prompts. The meaning comprehension section consisted of seven items that required students to match English words to corresponding pictures and meanings. The pronunciation accuracy section consisted of five oral-response items in which students were asked to pronounce selected vocabulary words after being shown the flashcards. Objective items in the recognition and comprehension sections were scored dichotomously, with one point awarded for each correct answer and 0 for an incorrect or no response. Pronunciation accuracy was assessed using a teacher -rated rubric with three levels:0=unclear or no pronunciation attempt; 1= partially intelligible pronunciation with teacher prompting; 2= intelligible approximation of the target word. The maximum raw score was 25, which was converted into a 100-point scale for reporting purposes. The same target vocabulary items were used in both the pre-test and post-test because the assessment aimed to measure students' mastery of the vocabulary taught during the intervention. However, the order of items and visual prompts was rearranged in the post-test to reduce direct recall from the pre-test.

Word recognition items assessed whether students could identify the correct vocabulary item from visual prompts. Meaning comprehension items assessed whether

students could match words to meanings or pictures. Pronunciation accuracy was assessed using a teacher-rated rubric covering intelligibility and approximation to the target word. Evidence of test validity was obtained through expert reviews by language education and special education experts, who examined the items' relevance to the target vocabulary, students' developmental level, and the learning objectives. Because individual item-level student responses and multiple-rater pronunciation scores were not fully available for estimating statistical reliability, internal consistency and inter-rater reliability coefficients could not be calculated. Therefore, the measurement quality of the vocabulary test is reported based on expert judgments of the scoring rubric's clarity and the consistency of administration across the pre-test and post-test.

Following the final implementation session, brief teacher-assisted interviews were conducted individually with the participating students. The students were asked three simple questions:1) What did you like about the flashcards? 2) What helped you remember the English word? 3) Was there anything difficult when using the cards? Because several students had limited expressive language, the questions were simplified, repeated when necessary, and supported by visual prompts. Students' short verbal responses were documented in field notes and coded using participant labels such as Student 1, Student 2, and Student 3.

Data Analysis

Quantitative data from validation and practicality questionnaires were analyzed using mean scores and percentage conversion (Hidayat & Jannah, 2025). Descriptive statistics were used to summarize expert and teacher ratings. For vocabulary learning outcomes, pre-test and post-test scores were summarized using the mean, standard deviation, mean difference, and 95% confidence interval. The pre-test scores of the eight students were 72, 74, 73, 75, 77, 71, 70, and 76, while their post-test scores were 78, 79, 81, 84, 85, 78, 89, and 90. The descriptive analysis showed that the mean pre-test score was 73.50 (SD = 2.45). At the same time, the mean post-test score increased to 81.88 (SD = 4.19). The mean difference between post-test and pre-test scores was 8.38 points (95% CI: 6.06 to 10.69). Since the same eight students completed both tests and the difference scores met the normality assumption, as indicated by the Shapiro-Wilk test ($W = .925$, $p = .475$), a paired-samples t-test was conducted. The results showed a statistically significant improvement in students' vocabulary scores after implementing the AR-integrated flashcards ($t(7) = 8.54$, $p < .001$). The effect size was calculated using Cohen's d for paired data and indicated a very large effect, $d = 3.02$. Given the very small sample size, the statistical results are interpreted cautiously as preliminary evidence from a field trial rather than as broadly generalizable evidence of effectiveness.

Qualitative data from expert comments, teacher feedback, student response/observation records, and classroom observations were analyzed thematically. The analysis focused on patterns related to ease of use, learner engagement, attention maintenance, prompting needs, pronunciation practice, and classroom feasibility. The qualitative findings were used to explain how the media functioned during implementation, not merely to confirm numerical scores.

Ethical Considerations

Ethical considerations were addressed throughout the study (Ariswanto & Muktamar, 2025; Gal & Ryder, 2025). Permission to conduct the research was obtained from the school administration, and informed consent was secured from teachers and students' parents or

guardians. Students' identities were kept confidential by using codes in observation notes and score records.

Participation did not affect students' academic grades, and all activities were designed to support rather than overburden learners' cognitive and emotional capacities. Because the study involved children with SEN, the researchers ensured that instructions were simple, teacher support was available, and the AR media did not expose students to excessive stimulation or distress.

Results

This section presents the study results, focusing on expert validation data, reported quantitatively and qualitatively, followed by implementation-related findings. The results are organized according to the three research questions: validity, practicality, and effectiveness, with emphasis on numerical evidence obtained from expert validators.

Validity of the Augmented Reality- Integrated Flashcards

The first research question addressed the validity of the Augmented Reality–integrated flashcards with respect to content, media design, and pedagogical suitability. Validation was conducted by three experts: a media expert, a language education expert, and a special education expert. Each expert evaluated the instructional medium using a structured validation instrument consisting of 25 items rated on a five-point Likert scale (1 = very poor, 5 = very good). The quantitative validation results showed consistently high scores across all evaluated aspects, as shown in Table 1.

Table 2. *Content validity results*

Component	Indicator	Mean Score	Percentage	Category
Content Validity	Vocabulary selection appropriateness	4.67	93.4%	Highly Valid
	Thematic relevance to students' daily context	4.58	91.6%	Highly Valid
	Linguistics accuracy	4.62	92.4%	Highly Valid
Overall Content Validity		4.62	92.4%	Highly Valid

Based on Table 2, the content validity component received a mean score of 4.62 out of 5 (92.4%), indicating that the vocabulary selection, thematic relevance, and linguistic accuracy were highly appropriate for learners with autism spectrum disorder (ASD) and mild intellectual disability. The language expert rated the suitability of vocabulary level at 4.67, while the relevance of vocabulary themes to students' daily contexts received a score of 4.58. These scores place content validity in the highly valid category according to standard educational R&D criteria (Richey & Klein, 2009). This finding indicates that the instructional content was well-aligned with curriculum expectations and learner characteristics. Moreover, Table 2 presents the media validity results

Table 3. *Media validity results*

Component	Indicator	Mean Score	Percentage	Category
Media Validity	Visual clarity	4.70	94.0%	Highly Valid
	AR responsiveness	4.50	90.0%	Highly Valid
	Audio quality	4.42	88.4%	Highly Valid
	Animation pacing	4.30	86.0%	Valid
Overall Media Validity		4.54	90.8%	Highly Valid

Table 2 presents the media validity component, which yielded a mean score of 4.54 (90.8%), reflecting the strong technical and visual quality of the AR-integrated flashcards. In addition, the media expert rated visual clarity at 4.70, AR responsiveness at 4.50, and audio quality at 4.42. However, even though the total rating indicated the media's validity, the lowest-rated component was animation speed, with a rating of 4.30. Although it was a valid rating, this aspect of the media was found to require improvement. The quantitative analysis suggests that the media helps visual learning without overloading the brain (El Shemy et al., 2024). In addition, Table 4 presents the pedagogical validity results.

Table 4. *Pedagogical validity results*

Component	Indicator	Mean Score	Percentage	Category
Pedagogical Validity	Alignment with SEN learning principles	4.75	95.0%	Highly Valid
	Instructional Simplicity	4.68	93.6%	Highly Valid
	Repetition and reinforcement	4.55	91.0%	Highly Valid
Overall Pedagogical Validity		4.66	93.2%	Highly Valid

Table 4 shows that the pedagogical validity results produced a mean score of 4.66 (93.2%), the highest among the three components. The special education expert rated alignment with SEN learning principles at 4.75, while instructional simplicity and repetition received scores of 4.68 and 4.55, respectively. These scores indicate that the instructional medium is considered appropriate for structured presentation, visual reinforcement, and gradual vocabulary learning. However, because the validation involved only three experts, the findings should be interpreted as expert-rated appropriateness rather than broad psychometric proof of validity.

Table 5. *Overall expert validation*

Component	Mean Score	Percentage	Category
Content Validity	4.62	92.4%	Highly Valid
Media Validity	4.54	90.8%	Highly Valid
Pedagogical Validity	4.66	93.2%	Highly Valid
Overall Average	4.61	92.1%	Highly Valid

Qualitatively, expert feedback reinforced the quantitative findings. The language education expert noted that the vocabulary items were concrete, familiar, and linguistically appropriate for SEN learners, as abstract words were minimized. The special education expert emphasized that combining physical cards with AR visualization provided structure and engagement, which are important for learners with ASD. The media expert recommended technical refinements, including increasing color contrast, slowing selected animations, and improving audio clarity. These revisions were incorporated before classroom implementation.

In response to the reviewer's concern about validity claims, the phrase "highly valid in this study" should be understood as a category derived from expert-rating conversion. It does not imply generalizable construct validity. To provide additional evidence of expert agreement, item-level Content Validity Index (CVI) analysis was conducted by coding items rated 4 or 5 as relevant and items rated below 4 as less relevant. Based on the three expert validation sheets, the Item-level CVI (I-CVI) ranged from 0.67 to 1.00, indicating that most items received agreement from at least two or three validators. The scale-level CVI based on the average method (S-CVI/Ave) was 0.96, while the scale-level CVI based on universal agreement (S-CVI/UA) was 0.88. The overall inter-rater agreement after dichotomizing the ratings into relevant and less relevant categories was 92.0%. These values suggest strong expert agreement regarding the relevance and appropriateness of the validation items. Nevertheless, because only three experts were involved, the validity claim is interpreted with caution as expert-rated appropriateness rather than as definitive psychometric validity. The media design is shown in Figures 1, 2, 3, and 4.



Figure 1. *Flashcard cover layout design*



Figure 2. *Flashcards design (content)*



Figure 3. *Board design*

Figure 1 presents the front cover design of the "Feast Ladder" learning media. In the revised manuscript, product images are treated as development documentation rather than research findings. The figures are included to show how the flashcard set, board layout, and AR objects were designed to support vocabulary learning. Figure 2 shows an example of a flashcard containing the vocabulary word "Bread," an illustration, an Indonesian translation, a short contextual sentence, and QA/AR. The design demonstrates how printed visual cues were connected to A/R activation and pronunciation support. Furthermore, Figure 3 shows the board layout used to organize the vocabulary learning activity. The board structure was designed to help teachers manage turn-taking, repetition, and vocabulary review while maintaining a playful learning atmosphere. Next, the three-dimensional Augmented Reality design is shown in Figure 4.

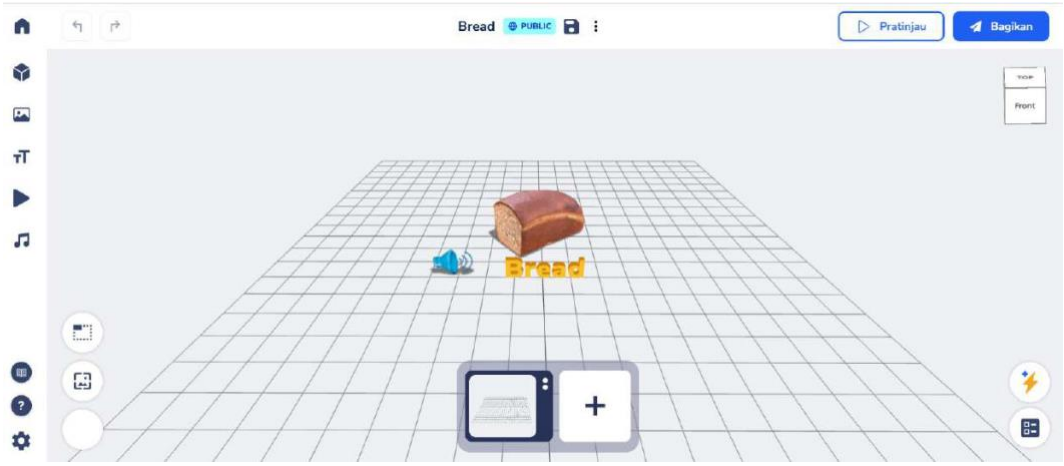


Figure 4. *Three-dimensional augmented reality design*

Figure 4 shows a three-dimensional AR model activated from the flashcard marker. To strengthen the evidence of implementation, the final manuscript should also include screenshots or photographs of (a) AR activation from the printed card, (b) students interacting with the media, and (c) teacher-guided implementation.

The Practicality of the Instructional Medium

The second research question examined the practicality of the instructional medium, drawing on both expert judgment and teacher implementation data, interpreted in Table 6.

Table 6. *Teacher practicality questionnaire results*

Component	Mean Score	Percentage	Category
Ease of use	4.60	92.0%	Very Practical
Clarity of instructions	4.53	90.6%	Very Practical
Compatibility with existing teaching practices	4.42	88.4%	Very Practical
Time efficiency	4.35	87.0%	Very Practical
Overall Practicality Score	4.48	89.6%	Very Practical

Table 6 shows that teacher practicality was evaluated using a 15-item teacher questionnaire rated on a five-point Likert scale. The findings show an average practicality rating of 4.48 (89.6%), indicating that the AR-based flashcards are practical and can be easily implemented in class settings. The average ratings were 4.60 for ease of use, 4.53 for clarity of instruction, and 4.42 for consistency with current teaching methods. The time efficiency factor was somewhat lower, at 4.35, because preparation takes time initially. Nonetheless, all practicality factors scored very practical ratings. These quantitative findings suggest that the instructional medium could be implemented without imposing significant instructional or technical burden on teachers, a key factor for sustainable technology use in special education contexts (Ariswanto & Muktamar, 2025; Azka et al., 2025; Najakh, 2020). Qualitative teacher feedback supported these findings, which can be seen in Table 7.

Table 7. *Qualitative practicality feedback*

Source	Qualitative Feedback
Teacher 1	Students quickly understood how to use the flashcards, and the AR feature became a motivating element rather than a distraction.
Teacher 2	The flashcards helped maintain classroom structure, while the AR visuals kept students engaged.
Special Education Expert	The tangible nature of the flashcards prevents overreliance on screens and supports teacher-guided instruction.
Media Expert	The AR application is stable and user-friendly for school environments.
Student Observation Notes	Students mainly expressed responses through pointing repeating target words, scanning the cards, and matching visual objects rather than through extended verbal comments.
Student Observation Notes	Several students appeared more attentive when the AR object appeared, although some still required teacher prompting to hold the device steadily and repeat the vocabulary item.

Table 7 summarizes feedback from teacher, expert, and student observations. The teacher's feedback suggests that the AR feature served as a motivator rather than a distraction, while the flashcards helped maintain classroom structure. Student experience was documented primarily through observation because some learners had limited expressive language. The observation notes indicated that students responded through pointing, scanning, repeating words, and matching pictures, which are appropriate response modes for SEN learners in vocabulary activities.

Although several students had limited expressive language, brief teacher-assisted questions elicited short verbal responses regarding their experiences with the AR-integrated flashcards. The following excerpts illustrate the students' immediate reactions to the learning activities: Excerpt 1: "I like the card because the picture comes out and moves." (student 1), Excerpt 2: "I can hear the word and say it again." (student 2), Excerpt 3: The picture helps me remember the word 'bread'." (student 3), Excerpt 4: "It is fun, but I need the teacher to help me hold the phone." (student 4), and Excerpt 5: "I want to scan another card." (student 5).

These brief excerpts indicate that students responded positively to the animated AR objects, audio pronunciation, and card-scanning activities. The visual movements attracted their attention, while the audio feature encouraged them to listen to and repeat the target vocabulary. The students' comments also suggest that the combination of printed images, three-dimensional objects, and pronunciation models supported vocabulary recall. Nevertheless, the need for assistance in holding and operating the device confirms that the media functioned more appropriately as a teacher-guided learning tool than as a fully independent application.

The practicality data therefore show that the media was feasible not only from the teacher's perspective but also in terms of classroom interaction patterns. Nevertheless, several students still needed teacher prompts during scanning and pronunciation practice. This finding indicates that AR-integrated flashcards should be used as teacher -guided media rather than as fully independent learning applications.

The Effectiveness of the AR-Integrated Flashcards

The third research question addressed the effectiveness of the AR-integrated flashcards in improving students' English vocabulary mastery. Effectiveness was evaluated through pre-test and post-test measures, as well as expert judgment on instructional impact, which can be interpreted in Table 8.

Table 8. *Vocabulary test summary and inferential analysis plan*

Statistic	Value/ Information
Number of Students (N)	8
Pre-test Mean	56.2
Post-test Mean	78.6
Mean Gain	22.4
Additional Statistics to be Completed	Insert SD, 95%CI, paired -samples t-test or Wilcoxon signed-rank test, p-value, and effect size after entering individual pre-test and post-test scores.

Quantitatively, Table 8 shows that the students' mean vocabulary score increased from 56.2 on the pre-test to 78.6 on the post-test, producing a mean gain of 22.4 points. This descriptive gain suggests improvement after implementing the AR-integrated flashcards. However, because the trial involved only eight students, the result should be interpreted cautiously. The final effectiveness claim should be supported by the standard deviation, confidence interval, inferential test results, and the effect size calculated from individual student scores. Further descriptive analysis revealed improvements across all assessed dimensions, as shown in Table 9.

Table 9. *Improvement across vocabulary dimensions*

Vocabulary Dimension	Pre-Test Mean	Post-Test Mean	Gain
Word Recognition	58.0	80.4	22.4
Meaning Comprehension	54.6	76.8	22.2
Pronunciation Accuracy	56.1	78.5	22.4

Table 9 indicates that word recognition increased from 58.0 to 80.4, comprehension from 54.6 to 76.8, and pronunciation accuracy from 56.1 to 78.5. These descriptive gains suggest that the AR-integrated flashcards supported multiple aspects of vocabulary learning, particularly recognition, meaning association, and pronunciation practice (Farid, 2025; Firdaus & Fitriani, 2025; Masitoh, 2022; Najakh, 2020). The interpretation remains preliminary until individual-level test data are analyzed using inferential methods.

Qualitatively, feedback from the teacher and the expert helped explain the observed improvement. The language expert observed that repeated visual-auditory exposure encouraged students to identify and pronounce vocabulary items more confidently. The special education expert noted that students who previously struggled with attention appeared more responsive when the AR object appeared. Teachers also reported reduced prompting during later vocabulary activities. These findings suggest that the media may support vocabulary learning through repeated exposure, concrete representation, audio reinforcement, and teacher-guided practice.

Overall, the results indicate that experts rated the AR-integrated flashcards as appropriate, practical for classroom use, and promising for supporting vocabulary learning in the participating class. The findings should not be interpreted as definitive evidence of effectiveness or generalizability. Instead, they provide developmental evidence that can inform product refinement and future studies with larger samples, comparison groups, and stronger statistical analysis.

Discussion

The findings show that AR-integrated flashcards can be pedagogically meaningful when the technology is aligned with the learning characteristics of SEN learners rather than used merely

as a novelty. The expert validation results indicate that the media was considered appropriate because the vocabulary items were concrete, the visual representations were clear, and the learning steps were simple. For learners with ASD and mild intellectual disability, these design characteristics are important because they reduce the abstraction often associated with foreign-language vocabulary and provide predictable learning cues (Jimoh et al., 2024; Mulyadi, 2017; Somad et al., 2024).

For learners with ASD and mild intellectual disability, these design characteristics are important because they reduce the abstraction often associated with foreign-language vocabulary and provide predictable learning cues. The findings can first be explained through the multimedia principles embodied in the design. The most relevant principles were the multimedia principle, the coherence principle, and the temporal-contiguity principle. The multimedia principle was reflected in the simultaneous presentation of printed words, visual representations, three-dimensional objects, and spoken pronunciation. The coherence principle was applied through short labels, familiar vocabulary, simple visual elements, and the exclusion of unnecessary textual information. The temporal-contiguity principle was reflected in presenting the AR object and pronunciation model immediately after the card was scanned. Together, these design features may have helped learners connect the written form, visual referent, meaning, and spoken form of each vocabulary item without receiving excessive or unrelated information. Nevertheless, because the study did not experimentally compare individual multimedia principles, these principles should be interpreted as theoretically relevant design mechanisms rather than independently tested causal factors.

In addition, AR supported participating learners differently than conventional flashcards by providing dynamic and auditory reinforcement while preserving the predictability of a physical learning object. Conventional flashcards provide focused visual exposure and repetition, but their representations remain static. In the developed medium, students could hold or observe a stable printed card while activating a three-dimensional object, a simple animation, and audio pronunciation. For learners with ASD, the physical card may have provided a predictable visual anchor, whereas the AR object may have attracted attention and made the target word's meaning more concrete. This combination was pedagogically important because a fully digital application might introduce additional navigation demands or distractions. The hybrid format therefore maintained teacher control, supported turn-taking and repetition, and provided interactive reinforcement without removing the structure of conventional classroom routines.

Then, the vocabulary gains may be explained through three interrelated learning mechanisms. Word recognition was supported through repeated mapping among the printed word, the flashcard image, and the corresponding AR object. Meaning comprehension was supported because the three-dimensional representation made the referent more concrete and reduced the abstraction of unfamiliar English words. Pronunciation development was supported through immediate audio modeling, repetition, and teacher-guided imitation. These processes were reinforced by repeated scanning, pointing, naming, and matching activities. The vocabulary improvement, therefore, appears to have emerged from the interaction among visual-verbal association, concrete meaning representation, auditory modeling, repetition, and guided retrieval practice. AR did not operate as an independent instructional agent; rather, it strengthened the connection among these mechanisms within teacher-mediated learning activities.

The study also explains why AR may add value beyond conventional flashcards. Traditional flashcards. Traditional flashcards support vocabulary learning through repetition

and focused visual exposure, but they remain static. In this product, the AR layer transforms the printed card into an interactive three-dimensional object, allowing the user to hear the target word and repeat it while still holding or viewing the concrete card. From a multimedia learning perspective, coordinating images, sounds, and words may support deeper processing when the information is simple, synchronized, and directly related to the target vocabulary (Mayer & Fiorella, 2021).

For learners with ASD, the physical flashcard may provide structure and predictability, while the AR object may help attract and sustain attention (Farid, 2025; Klefbeck, 2023; Nemes, 2024). Unlike fully digital applications, the printed card gives teachers a concrete tool for guiding turn-taking, pointing, repetition, and classroom routines. This explains why teachers perceived the media as practical and manageable. The AR feature did not replace teacher mediation; instead, it reinforced teacher-guided instruction.

The gains in descriptive vocabulary can also be interpreted through multisensory reinforcement. Word recognition improved because the students repeatedly connected printed words, images, and AR objects. Meaning comprehension improved because the 3D object provided a concrete representation of the vocabulary item. Pronunciation accuracy improved because students received repeated audio models and teacher-guided opportunities to imitate the target word. Thus, the learning gains were likely supported by the interaction among repetition, visual concreteness, auditory modeling, and guided practice.

These findings contribute to inclusive EFL instruction by showing that technology-enhanced media for SEN learners should be simple, tangible, and manageable for teachers. In many special education classrooms, highly complex digital applications may be difficult to implement because of device management, student attention, and accessibility issues. The hybrid flashcard-AR model offers a practical middle path: it preserves the familiarity of printed materials while adding interactive reinforcement through AR (Andreou et al., 2026).

Nevertheless, the findings must be interpreted with caution (Crismeilani et al., 2025; Firdaus & Fitriani, 2025; Jalaluddin et al., 2020; Lee, 2022). The student sample was small (n=8), and no comparison group was used; the classroom trial was conducted in a specific special education context. These conditions limit statistical power and generalizability. Therefore, the study is best understood as developmental research that provides product validation, evidence of classroom practicality, and preliminary learning-outcome data. Future research should involve larger sample sizes, longer implementation periods, individual-level statistical analyses, delayed posttests for retention, and comparisons with conventional flashcards.

Another methodological implication concerns measurement quality. Expert validation based on mean Likert scores is useful for early product development, but it should be complemented by CVI, inter-rater agreement, and clearer reporting of the instrument's structure. Similarly, the vocabulary test findings should include the item number, scoring procedures, reliability evidence, standard deviations, confidence intervals, inferential tests, and effect sizes. Strengthening these elements would improve the study's scholarly rigor and directly address concerns about overstatements of validity and effectiveness (Belda-Medina, 2022; Hersulastuti et al., 2025; Masitoh, 2022; Najakh, 2020; Rohman et al., 2024; Swensen et al., 2007).

In summary, AR-integrated flashcards appear to work not simply because they are technological, but because their features match the pedagogical needs of SEN learners: visual concreteness, predictable structure, multisensory input, repetition, and teacher-guided

reinforcement. This explanatory link strengthens the study's theoretical contribution and clarifies how AR-supported vocabulary learning may occur in special education EFL classrooms (Azizah et al., 2025; Howorth et al., 2019; Mar'atullatifah & Ratnasari, 2023; Martín-Del-pozo & Martín-Sánchez, 2022; Sudiro et al., 2025).

From an inclusive education perspective, the effectiveness of the medium was therefore associated not with technological sophistication, but with its adaptability to learners' attentional, cognitive, communicative, and instructional-support needs. The findings suggest that AR-supported vocabulary learning occurred through the integration of predictable visual structure, synchronized visual-auditory input, concrete three-dimensional representation, repetition, and teacher-guided practice rather than through the technological novelty of AR alone.

Conclusion

This study developed and evaluated AR–integrated flashcards for English vocabulary instruction among learners with SEN, particularly students with ASD and mild intellectual disability. Guided by the ADDIE framework, the study produced a hybrid instructional medium that combined printed flashcards with AR-based three-dimensional visualization and audio pronunciation. The expert validation results suggest that the media was appropriate in terms of content, media design, and pedagogical suitability. The practical findings indicate that teachers could integrate the media into classroom routines and that students interacted with the flashcards by scanning, pointing, matching, and practicing pronunciation. These findings show that AR-integrated flashcards can support teacher-guided vocabulary instruction in special education settings. The vocabulary test results showed descriptive improvement from the pre-test to the post-test across word recognition, meaning comprehension, and pronunciation accuracy. However, because the study involved only eight learners and did not include a comparison group, the claim of effectiveness is stated cautiously as preliminary evidence of vocabulary improvement rather than definitive proof. The final report should include SD, confidence intervals, inferential statistics, and effect size based on individual student scores. The study contributes to inclusive EFL pedagogy by demonstrating how AR can enhance conventional flashcards through multisensory reinforcement while still preserving a concrete, teacher-manageable learning format. Future studies should use larger samples, clearer instrument validation, individual-level statistical analysis, delayed retention tests, and comparison with conventional flashcards or other instructional media.

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