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The Impact of Augmented Reality (Ar) on Vocabulary Acquisition in Elementary School Students

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ABSTRACT

Vocabulary development is one of the key areas in learning English as a second/foreign language, especially for children. New technologies, including Augmented Reality (AR), provide an interactive and immersive learning environment which can enhance vocabulary retention in a more engaging way. Despite increasing interest, studies on long-term effects and AR application in elementary education are still scarce. The purpose of this research is to analyze the effect of AR on English vocabulary knowledge of elementary school students. A quasi-experimental one-group pre-test and post-test were undertaken with a sample of 25 fifth grade students of SDN Jambon 2-Yogyakarta. Data was collected through vocabulary proficiency tests of CEFR A1–A2 levels and student perception questionnaires derived from established instruments. Descriptives and inferential statistical analyses were utilised – (paired sample t-tests and the calculation of effect sizes). The pre-test data showed that students' mean scores of vocabulary were in the category of "Fair" (M = 61.56), as most participants encountered difficulties in pronunciation, spelling, meaning interpretation, and contextual usage. The average posttest score rose significantly to 83.20 in the "Proficient" rank after the AR intervention phase. The change was statistically significant (p = 0.000, t = 8.996), which indicated that AR had a significant positive effect on vocabulary learning. Findings indicate that vocabulary learning is positively influenced by AR-supported learning experience, providing students with a dynamic and joyful learning space. The research highlights AR's promise as a pedagogical medium in elementary level English education, with empirical evidence for its implementation in technology-enhanced language learning.

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1. INTRODUCTION

Learning English as a second or foreign language is an intrinsic part of building vocabulary, as well as communication networks and overall language skills. Vocabulary is mainly supposed to look for in both as a receptive and productive skills (listening, reading, writing and speaking) as the learner should not only identify and understand the words, but s/he should also use words accurately and contextually within several semantic systems (Faizah, Drajati, & Yunus, 2022). In addition, as Agazzi (2022) further highlights, vocabulary learning is crucial for children as it paves the way for successful language and cognitive development. There are, however, many Indonesian learners who still find difficulty with scene descriptions. This can be seen in the 2023 Programme for International Student Assessments (PISA) for Indonesian students, who recorded a much lower reading literacy level than their counterparts in other countries, like Singapore or South Korea. These results underlie the pressing concern for more creative and efficient methods of vocabulary instruction in Indonesian classrooms. Old ways, such as textbooks and memorisation, may not be adequate to engage students and accommodate their varied learning styles. As a result, technology-enhanced learning, like Augmented Reality (AR), has become appealing and an alternative for vocabulary instruction, to provide enhanced, interactive, and immersive learning experiences tailored to the cognitive profiles and interests of young learners (Vasista, 2022).

The potential of technology-supported learning as a means of promoting vocabulary has grown in importance recently, as traditional approaches to teaching vocabulary (leading often to demotivation among learners) are losing force. Among different digital novelties, Augmented Reality (AR) proves to be the most promising technology capable of converting the traditional approach of passive vocabulary acquisition into a more interactive and virtual practice. As Gavranović (2019) points out, technology has the potential to improve

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foreign language teaching by providing interactive and multimodal learning spaces. Moreover, AR enhances student engagement and understanding effectively in vocabulary learning given the importance of visualization and contextualization as verbs of seeing (Huang, 2021). Unlike traditional techniques like flashcards and rote learning, AR ensures the learner can engage with 3D objects and spaces and learn in simulation environments that reflect real-world contexts, increasing understanding and recall of information. Sadikin and Martyani (2020) agree with this view and show that AR enhances learner motivation and participation in experiential learning. Altogether, these studies imply that AR is no longer a supplementary technology but a powerful pedagogical approach that can overcome some longstanding problems in learning English vocabulary among students.

Meanwhile, as promising as it is from a pedagogical point of view, the integration of AR into educational contexts still faces numerous challenges that need to be carefully addressed. One of the main causes is the continued, traditional use of textbook–based instruction, which frequently limits the extent to which students are exposed to/receive information on the target vocabulary. As stated in Puspitarini and Hanif (2019), this excessive dependence on static learning material decreases students 'motivation and the level of the vocabulary learned. Adherents to this dialogic position believe that the instruction is more powerful if learners are given the opportunity to use language in context rather than in decontextualised and predictable forms, and that the retention of structures introduced in this way is greater than in traditional forms of teaching. Furthermore, although AR is promising to better vocabulary development, its wider generalizability and sustainability are still not well known. Belda-Medina and Marrahi-Gomez (2023) note that studies to date generally address the short-term effects of AR, while long-term effects and the transferability to various educational contexts remain largely unexplored. Such gaps highlight the need for a more inclusive investigation on one hand that looks at learning outcomes over time, while examining on the other the structural, pedagogical, and teacher development issues, which hinder teachers in using AR as an everyday classroom practice. These are the problems that need to be resolved if AR is going to reach the potential that it should for being a transformative tool in language learning.

Several empirical works have elucidated the possible role of AR in vocabulary growth (Belda-Medina & Marrahi-Gomez, 2023; Binhomran & Altalhab, 2021; Criollo-C et al., 2024; Puspitarini & Hanif, 2019; Zhang et al., 2020). These results confirm AR's potential to improve learners' vocabulary, motivation, and context learning. Yet, there are still big gaps, especially in terms of the long-term sustainability of the AR as well as how feasible it is within the context of the national education system of Indonesia. "Barriers to widespread adoption of AR-based learning solutions include factors such as lack of access to technological infrastructure, inadequate teacher training, and ongoing reliance on traditional pedagogies."

In thus striving to fill these gaps, this study explores the use of AR in a localized educational environment –SD Negeri Jambon 2, Yogyakarta, where students constantly experienced problems with the mastery of their English vocabulary. Research seeks to investigate how AR can be utilised to promote vocabulary learning, the significance of the study among primary school students, investigate the challenges in the use of AR, and determine if the AR-based approach is better than traditional ones. To direct this inquiry, the research focuses on three primary questions: (1) What are the difficulties students encountered in developing their mastery of English vocabulary? (2) How does AR affect the students' vocabulary learning as opposed to the traditional method? and (3) What are the challenges that interfere with AR in elementary school language learning? By focusing on these questions, the study makes a context-bound contribution to the now burgeoning literature on technology in language education and has implications for practitioners and policymakers in Indonesia.

The aims of the study correspond to the research questions and thus, aim to produce an in-depth image of the AR application in vocabular y learning with young learners. More specifically, the project's goals are: (1) to uncover the main problems in learning English vocabulary experienced by elementary school students; (2) to ascertain whether AR is effective as a pedagogical tool when compared to the conventional method for learning vocabulary; and (3) to evaluate the possibility of implementing AR in the current FL learning system at the elementary school level in Indonesia. By methodologically systematically addressing these goals, the research aims to provide valuable perspectives to inform how AR could be used to aid vocabulary learning and surpass pedagogical predicaments. Importantly, the findings are also intended to be used to develop contextually rich, practical, evidence-based guidelines for the implementation of AR technology in early language education with an aim to providing more engaging, effective and fair English learning opportunities for young learners. They will develop practical, context-sensitive strategies to help teachers modelling the implementation of AR technology

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in early language education which can be adaptable and applied for English language learners' own learning and for other teacher oral skills training in other areas as needed.

2. MATERIAL AND METHOD

Research Design

The present study was conducted using quantitative research method with one-group, pretest-posttest design to examine the effectiveness of Augmented Reality (AR) in improving students' vocabulary acquisition. This quasi-experimental design is an appropriate choice for educational research, in which complete randomization is often not practical, but it enables researchers to study causal relationships among pre-existing groups (Singh, 2021). According to Creswell and Creswell (2018), quasi-experimental designs typically have few controls on independent variables and use intact groups, which is useful in a classroom setting.

Adopting the one-group pre-test post-test design in this investigation was as a result of logistic restrictions, including the non-availability of a similar control group. Notwithstanding this limitation, the design served well to provide a clear gauge of learning outcomes in between the GA retellings and pre/post intervention administrations with the AR app. The authors admit to threats to internal validity, such as maturation effects, and to extraneous variables that have not been controlled for. In order to cope with these problems, a pre-test-pot-test was duly administered to achieve the improvement of the efl students' vocabulary over time.

The study procedure was organized in three consecutive steps: (1) a pre-test, which was implemented as the first step as a measure of vocabulary knowledge at the start of the program, (2) during the program when the students receive AR-assisted vocabulary instruction, and (3) a post-test as the third step of the study process to evaluate vocabulary knowledge at the completion of the implementation of the study. These stages were conducive to a more detailed examination of the instructional effect of AR on student achievement. This design, played a catalyst role in peer to peer collaborative AR learning scenario, which is then being further developed and may extended in other schools also. We Will be able to gain more practical insights of AR application in real classroom through this design.

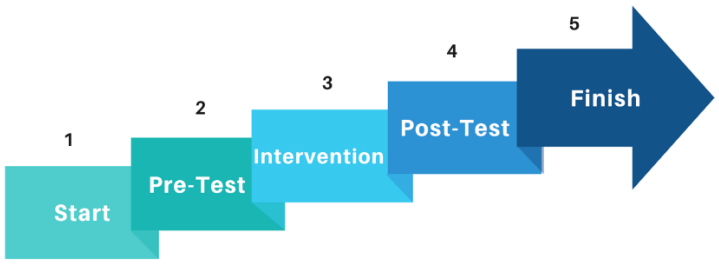

Figure 1. The research process

Participants

Participants were 25 fifth graders (mean age: 10 years and 8 months) from SD Negeri Jambon 2 who had low to moderate proficiency in English. The last sample size (N = 25) was obtained by excluding participants in the initial profiling sample who did not meet criteria for comparable baseline vocabulary knowledge. The target school was selected because it had previously expressed interest in integrating technology into language teaching, and because the institution could support the research practice.

Because participants were children, ethical standards were closely adhered to at all times. Formal permission of the school administration and written informed consent from the students parents/guardians were also received before data collection. A classroom teacher acted as a "go between", in facilitating communication between the author and parents and in explaining in detail the purpose and process of the study to the parents. Consent was also obtained from the students to ensure that their participation was voluntary and all the students understood it. They helped main ethical standards, especially in protecting rights and well-being of the young participants.

Research Instruments

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The study employed two primary data collection instruments: a questionnaire and a vocabulary proficiency test, each carefully designed and adapted to suit the context of young English language learners and to align with the research objectives. To explore students' difficulties in learning English vocabulary, a structured questionnaire adapted from Lutfiyah (2022), originally titled *The Obstacles in Learning Vocabulary of EFL Students*, was used. This instrument comprised 10 items aimed at identifying the frequency and nature of vocabulary learning challenges. For this study, the questionnaire was modified in wording to better reflect the specific research context while maintaining the original intent, and it was administered prior to the intervention phase to gather baseline data on students' perceived vocabulary learning barriers. The vocabulary proficiency test, meanwhile, was developed based on the Common European Framework of Reference for Languages (CEFR), specifically targeting A1 and A2 levels as recommended by the British Council for early-stage learners. Comprising 30 short-answer (essay-type) questions, the test assessed three dimensions of vocabulary knowledge: spelling, meaning, and contextual usage. Test items were age- and level-appropriate for elementary students, maintaining pedagogical rigor. Content validity was ensured through expert judgment, while reliability was confirmed using Cronbach's alpha, establishing strong internal consistency and measurement accuracy.

Data Analysis

Descriptive and inferential, statistics were used to analyse the data. Trend identification, response distribution and summary of students' vocabulary learning difficulties were presented in the form of descriptive statistics of students' progress over the intervention period. These data offered a snapshot of the general occurrence of vocabulary knowledge before and after the AR intervention treatment. To evaluate whether parametric statistical tests could be used, data distribution normality was tested by Shapiro-Wilk test. A p-value > 0.05 was considered as evidence of normal distribution of the data. This procedure helped to guarantee that the assumptions of parametric tests were sufficiently satisfied, and the results of the Shapiro-Wilk test were described in order to be as transparent as possible in our statistical decisions. To test hypotheses, a paired-samples ttest was performed to compare pre-test and post-test vocabulary scores. For the analysis, a confidence level of 95% and a p—value cut-off of 0.05 were used. Moreover, the magnitude of the intervention's effect was estimated as an effect size using Cohen's d. Cohen's d effect sizes were defined as small (0.2), medium (0.5), and large (0.8). Using these statistical procedures, the purpose of this study was to provide a valid, research-based measurement of the impact of (AR) on students' vocabulary learning. These results should also have implications for the general discussion on technology integration in language learning and its pedagogical implications at elementary level.

3. RESULTS

The Problems do Students Face to Enhance Their English Vocabulary before being Treated with Augmented Reality

According to the results, students' problems in learning vocabulary are classified into four major groups including pronunciation and spelling, word meaning, use and connotation. These categories are indicative of the complexity of developing a rich English vocabulary in young ELs. The specific problems students face are described in the following section (Table 1); an index of students' responses to their specific areas of difficulty is outlined.

Table 1. Problem student face is pronunciation and spelling

No.	Instrument Statement	Scale			
		Strongly Agree	Agree	Disagree	Strongly Disagree
Pronunciation and spelling:					
1.	I feel difficult in learning vocabulary because there is difference between the spelling and pronunciation of the word	32.0%	44.0%	16.0%	8.0%
2.	I got difficulty in vocabulary because of the difference between Indonesian and English spelling	40.0%	36.0%	20.0%	4.0%
3.	I feel difficult in vocabulary mastery because of the words or sounds spelling mismatch	52.0%	28.0%	16.0%	4.0%

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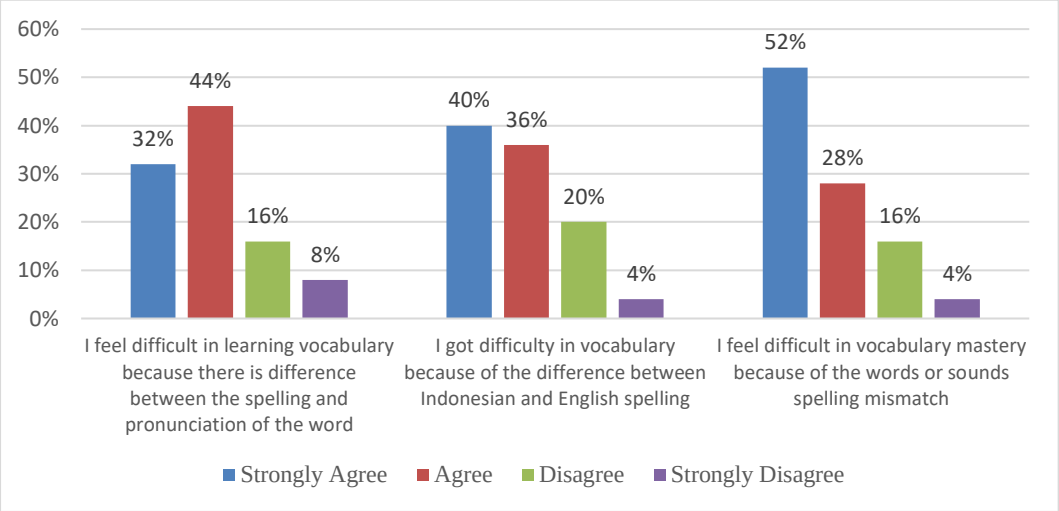

Figure 2. Problems students face is pronoun and spelling

As shown in Table 1, speaking and writing are difficult work for students to learn English vocabulary. In particular, 32% of students encountered problems with the differences between English spelling and pronunciation. Other obstacle: 40% stated due to the differences in orthographic of the two languages (English and Indonesian). In interestingly, fifty-two per cent of the students reported that they had difficulty in learning words because the pronunciation of words was different from their written form/meaning. These results also show that Phonological and orthographic complexities are great obstacle to acquiring new words for young learners. Discrepancy between spoken and written English seems to be a difficulty for SLV, which perhaps affects the student's internalization and use of new vocabulary, suggesting the relevance of instructional echoic practices that target these linguistic challenges specifically.

Table 2. Problem student face is word meaning

No.	Instrument Statement	Scale			
		Strongly Agree	Agree	Disagree	Strongly Disagree
Word meaning:					
4.	I feel difficult in vocabulary mastery in terms of synonyms and antonym	32.0%	48.0%	20.0%	0.0%
5.	I feel difficult in determining words' meaning correctly	44.0%	36.0%	16.0%	4.0%
6.	I feel difficult because some words are similar in form but different in meaning	36.0%	44.0%	16.0%	4.0%

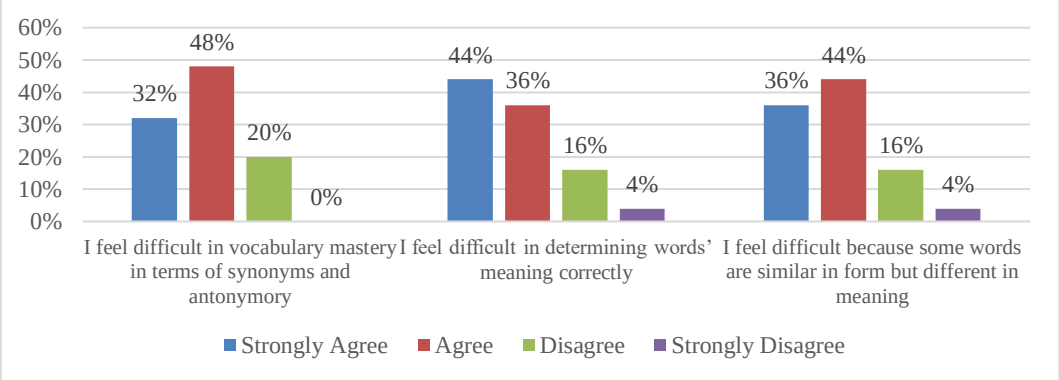

Figure 3. Problems students face is word meaning

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Data also show that students face significant difficulty in learning the meanings of words, especially the meaning of synonyms, antonyms and homonyms. The proportion of students who strongly agreed, and agreed that identifying and differentiating between synonyms and antonyms was very difficult were 32% and 48%, respectively. Forty-four percent also strongly agreed and 36% agreed that finding the right meaning of a word was difficult, particularly when there were several possible interpretations. These results indicate that semantic processing continues to be a significant barrier to vocabulary knowledge, beyond basic memorization and in the realm of nuanced understanding of word-to-word relationships. This highlights the need of instructional approaches that reach beyond superficial vocabulary exposure, i.e. by promoting contextual and semantic insights for more profound vocabulary development_following points should be added here or are unclear.

Table 3. Problem student face is word usage

No.	Instrument Statement	Scale			
		Strongly Agree	Agree	Disagree	Strongly Disagree
Word usage:					
7.	I feel difficult to use vocabulary appropriately because some words are restricted to use in particular context	76.0%	24.0%	0.0%	0.0%
8.	I feel difficult to give a well-known opposite or well- known word or lexical set it fits into a word or sentence	48.0%	52.0%	0.0%	0.0%

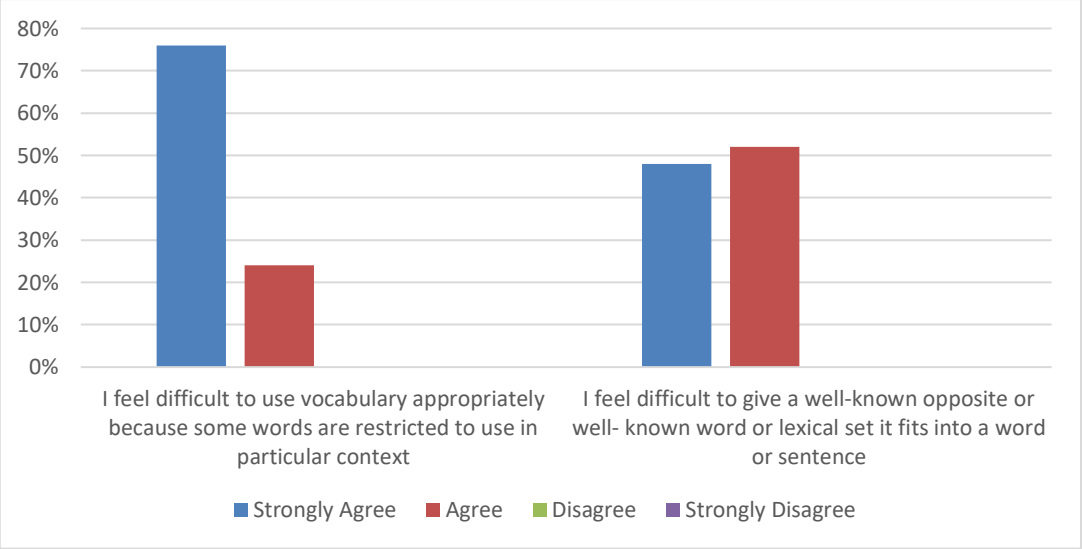

Figure 4. Problems Students Face is Word Usage

Another important issue observed in the study is the difficulty faced by students in using new words with context. The majority of students, 76% strongly agree and 24% agree, claimed to have problems using specific words because of their context-sensitive meanings and limited use in certain situations (see Table 3). Additionally, 48% strongly agreed and 52% agreed that they had difficulty providing appropriate antonyms or synonyms when formulating sentences. These results suggest an impairment in semantics and pragmatics of word use. It is not just the difficulty of understanding the literal sense of words, but also of using them appropriately in the diverse communicative situations. This highlights the importance of teaching vocabulary within context as a functional tool, rather than an isolated memorized word.

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Table 4. Problem student face is connotation

No.	Instrument Statement	Scale			
		Strongly Agree	Agree	Disagree	Strongly Disagree
Connotation:					
9.	I feel difficult in understanding the connotation of a word because the word have a positive or negative meaning	56.0%	36.0%	4.0%	4.0%
10.	I feel difficult in identifying the words connotation meaning	52.0%	40.0%	4.0%	4.0%

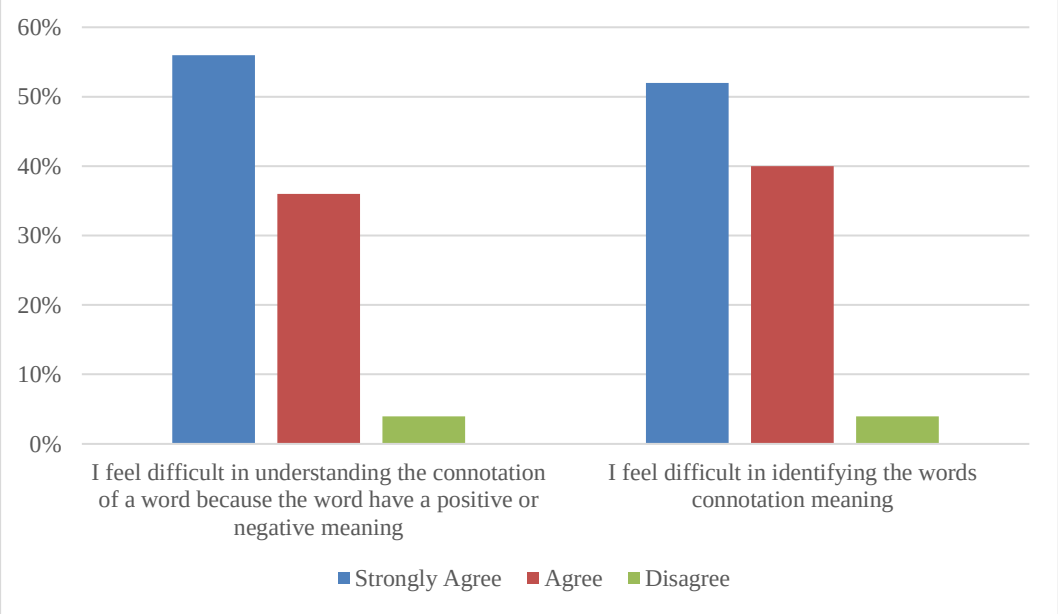

Figure 5. Problems Students Face is Connotation

In the last category connotation, data show that students also have much trouble in understanding the emotional or associative meanings of words. In particular, 56% of the students strongly agreed and 36% agreed that it was difficult to know whether a word had positive or negative connotations. Also, 52%, or a combination of 40% agreed plus 12% strongly agreed that they perceived it to be difficult to determine connotative meanings in typical vocabulary words in English. These findings reflect that the approach to understanding of student's is limited to elucidation of denotative (literal) meanings of words, and they may have the least sense about the affective and culture-specific implications. The results underscore a crucial deficiency in students' understanding of such things as inference, tone, and emotional context — all crucial to effective, subtle communication. There is hence the need for targeted teaching on connotative language, as students need to become more sensitive to the layers of meaning and the subtleties in English words, and be aware of the word‟s connotative implications.

The Level of Student Vocabulary Category before being Treated with Augmented Reality Technology

The students' vocabulary proficiency was measured by the scores from a sample vocabulary test and was analyzed by the researcher using a profiling framework based on Sardi (2022). The framework classifies mastery levels for the words according to the score ranges, which facilitates a straightforward interpretation of students' performance before and after the intervention. Below is the category, and the respective marks. Results and discussion The post- vocabulary test, which followed pre- vocabulary test was compared with the use of SPSS after the intervention of the Augmented Reality-AR. Descriptive statistics of this analysis has been shown below, which indicates students baseline scores of vocabulary proficiency prior to experiencing AR-enabled learning activities.

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Table 5. Value and category for vocabulary test

Category	Value	Pre-Test
Very Good	86 – 100	0
Good	71 – 85	5
Fair	56 – 70	12
Poor	41 -55	7
Very Poor	<40	1
Total	(N=25)	

Table 6. The Pre-Test Score

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Pre_Test	25	40.00	77.00	61.56	10.85
Valid N (listwise)	25				

The pre-test results (Table 6) suggest that students had a relatively poor to moderate vocabulary knowledge before the AR intervention. The scores varied between 40 (the lowest) and 77 (the highest) with a mean of 61.56. When compared with the classification data provided in Table 6, this average score is into the "Fair" (56–70), indicating that students had some basic vocabulary knowledge, but were generally low proficient. The relatively large standard deviation of 10.85 points indicates a large amount of variance in performance among the participants, with some students exhibiting skills at the level of the "Poor" category (41–55) and few students at the bottom end of the "Good" range (71–85). These results point to the heterogeneous linguistic competencies of students and the importance of targeted intervention to support vocabulary development in general, before more advanced language instruction.

The Level of Student Vocabulary Category after being Treated with Augmented Reality Technology

Following the implementation of the Augmented Reality (AR) intervention, the researcher evaluated students' vocabulary proficiency using the same classification framework applied in the pre-test, as adapted from Sardi (2022). The vocabulary test scores were categorized to determine the extent of improvement in students' mastery levels after the treatment. The results and corresponding classifications are presented in the table below.

Table 7. Value and Category for Vocabulary Test

Category	Value	Post-Test
Very Good	86 – 100	21
Good	71 – 85	3
Fair	56 – 70	1
Poor	41 -55	0
Very Poor	<40	0
Total	(N=25)	

Table 7 served as the reference for categorizing student vocabulary scores after the AR intervention. Using this classification framework, the post-test data were analyzed through SPSS to determine the extent of improvement in vocabulary proficiency. The descriptive statistical results from this analysis are presented below.

Table 8. The Post-Test Score

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Post_Test	25	63.00	100.00	83.2000	9.66523
Valid N (listwise)	25				

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The post-test scores in Table 8 show an overwhelming improvement in the students' vocabulary proficiency after The Augmented Reality (AR) intervention. The minimum grade jumped substantially to 63 and the maximum grade reported was 100, suggesting that all participants had scored at least a 'Fair' level (VI) or above on both versions of the passages presented in Table 8. The average increased significantly to 83.20 – group average now falling within the category of "Good" (71–85) with a mean pre-test score of 61.56. This assent corresponds with a significant improvement in general vocabulary knowledge. The standard deviation also decreased slightly to 9.67, which means the scores were more evenly distributed among students and the scores were less varied among students. Taken together, these results suggest the viability of the AR intervention for raising vocabulary performance and reducing the extent of variability in learning gains among the participant6s in the present sample.

The Use Augmented Reality (AR) Significantly Enhance Elementary School Students' Vocabulary

A normality test was performed first to investigate the normality of the pre- and post-test data prior to discussing the statistical significance of the treatment effect. The check of normality is an important prerequisite to any statistical test since it is what decides whether it is reasonable to use parametric tests. The normality of the data distribution should be checked to draw a valid interpretation of the inferential statistical results (Ridhollah et al., 2021). One-Sample Kolmogorov-Smirnov was chosen for current study as it is applicable in small sample size (N<50). If a p-value is above 0.05, then the data is normally distributed. The results from the normality test through SPSS appear in the table below.

Table 9. Normality Test

One-Sample Kolmogorov-Smirnov Test				
			Pre_Test	Post_Test
N			25	25
Normal Parametersa,b	Mean		61.5600	83.2000
	Std. Deviation		10.85541	9.66523
Most Extreme Differences	Absolute		.113	.133
	Positive		.105	.110
	Negative		-.113	-.133
Test Statistic			.113	.133
Asymp. Sig. (2-tailed)c			.200d	.200d
Monte Carlo Sig. (2-tailed)e	Sig.		.556	.291
	99% Confidence Interval	Lower Bound	.543	.280
		Upper Bound	.568	.303

a. Test distribution is Normal.

b. Calculated from data.

Table 10. Homogeneity Test

		Levene Statistic	df1	df2	Sig.
Vocabulary_Test	Based on Mean	.582	1	48	**.449**
	Based on Median	.392	1	48	**.534**
	Based on Median and with adjusted df	.392	1	47.081	**.534**
	Based on trimmed mean	.535	1	48	**.468**

Following the normality assessment, a homogeneity of variance test was conducted to determine whether the variances of the pre-test and post-test scores were statistically equivalent. This step is essential to validate the assumption of equal variances prior to conducting a paired-samples t-test. Levene's Test for Equality of Variances was applied for this purpose. A significance value (Sig.) less than or equal to 0.05 indicates that the null hypothesis (H_o) should be rejected, suggesting unequal variances across groups. Conversely, if the Sig. value

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exceeds 0.05, the null hypothesis is retained, indicating that the data exhibit homogeneity of variance. In this study, the results demonstrated a Sig. value greater than 0.05, thus confirming that the variances between the two sets of scores were statistically homogeneous and suitable for further parametric analysis.

When the normality of the data as well as homogeneity of variance was confirmed the appropriate statistical analysis was implemented as a paired-samples t-test. Before we present the statistical results, we used a boxplot (Figure 6) to compare the vocabulary score of the students graphically before and after intervention with focus on solving Word problem. This is obvious from the boxplot that shows quite a significant rise in the post-test scores as compared to the pre-test, which reflects an improvement in the vocabulary performance. Of interest, median scores increased and the range of scores was compressed, suggesting higher as well as more consistent performance across subjects. These visual trends provide evidence that the Augmented Reality (AR) intervention contributed significant value to participants' vocabulary learning, which is further established in the subsequent statistical analysis.

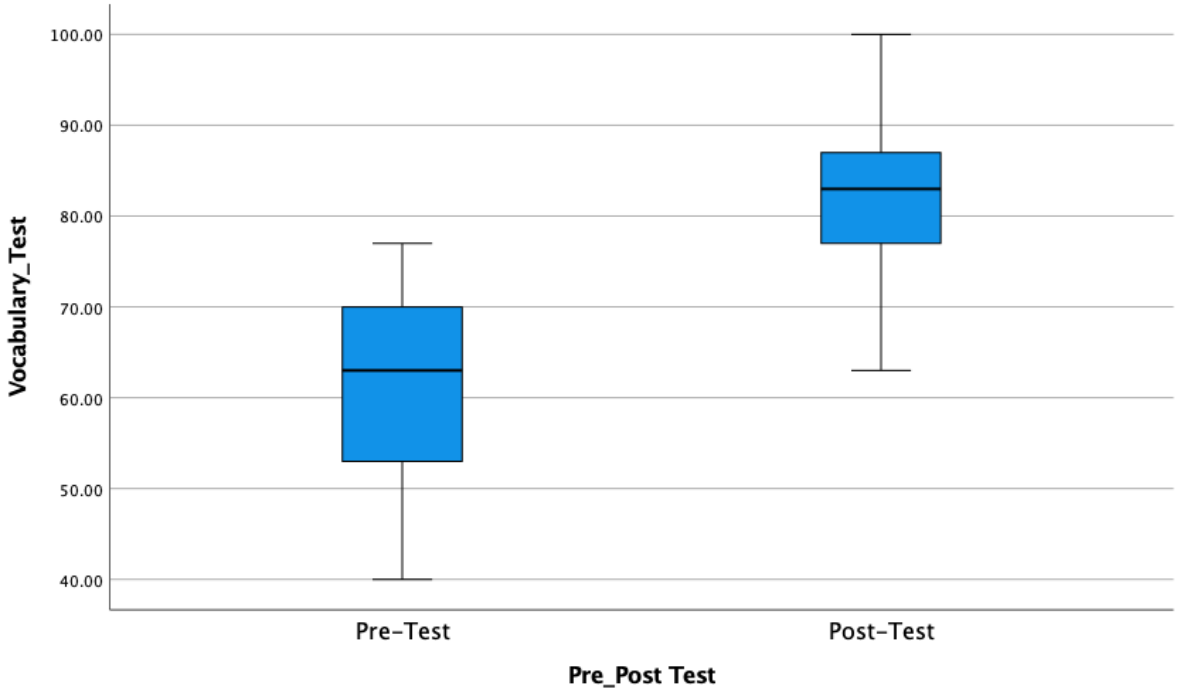

Figure 6. Boxplot Vocabulary Test

performance after AR intervention. Variability of pre-test scores were larger and that of post-test were clustered around the upper end of the scale showing that these learners became more uniform. The up movements of score range supra-totals make ease on the improvement of central group and maximum achievement. The absence of large outliers confirms the normal distribution assumption. Together, these visual patterns consolidated the tentative finding that the AR intervention was conducive to vocabulary learning.

Subsequently, after the semantic and visual inspection, a paired-samples t-test was performed, which assessed the statistical significance of the observed differences in vocabulary performance. The research used 95% confidence ($\alpha = 0.05$), thus 25 participants generated 24 degrees of freedom. From this the t critical value (from the t distribution table) was 1.708. The t-test outcomes obtained with SPSS are shown below to analyse whether the differences between pre-test scores and post-test scores are significant or not.

The results of the paired-samples t-test, as shown in Table 11, revealed a two-tailed significance value (Sig.) of 0.000, which is well below the threshold of 0.05 ($p < 0.05$). This indicates that the observed difference between the pre-test and post-test vocabulary scores is statistically significant. Accordingly, the null hypothesis (H_o), which posits no difference in students' vocabulary proficiency before and after the intervention, is rejected in favor of the alternative hypothesis (H_a), which asserts that the intervention led to a measurable improvement. In addition to the p-value, the calculated *t* value (t = 8.996) was compared to the critical *t* table value ($t_t = 1.708$, df = 24), further confirming the significance of the result as t_calculated > t_critical. These findings provide robust

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statistical evidence that the implementation of Augmented Reality (AR) had a meaningful and positive impact on students' vocabulary mastery

Table 11. Paired Sample Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Pre_Test - Post_Test	-21.64	12.03	2.40	-26.60	-16.67	8.996	24	**.000**

4. DISCUSSION

Vocabulary Learning Challenges

To summarise this section of the survey, a large proportion of students seemed to experience considerable trouble with spelling and pronunciation. This was particularly true for the statement 'Spelling of words in English is not often pronounced how it is spelt', which was reported most frequently agree (76.0%). These findings imply that the English's phonological and orthographical irregularity is one of the obstacles for learners. Moreover, a majority of students (80.0%) found it challenging to make sense of word meanings, in particular to identify synonyms and antonyms as well as a more in-depth level of semantic understanding. Vocabulary use, particularly in word collocation and sentence patterning, was also found to be a significant barrier: 90.0% of participants expressed difficulty with this issue. Lastly, determining word connotations—whether a word has a positive or negative connotation—is one of the most problematic, cited by 92.0% of students.

This corresponds to the study conducted by Krisnayanti and Winarta (2021) that the most difficult for students in learning vocabulary was pronounced and spelling of words in Indonesia. Moreover, Leano et al. (2019) pointed out that learners often face difficulties to understand the precise meaning of English words which include synonyms and antonyms. Susanto (2021) supports these findings by stating that students often have difficulties in pronouncing, spelling, and using vocabulary in the right context. In addition, non-native English learners frequently struggle to discern the multiple meanings associated to words depending on the context of their up-to-expressed utility (Salman, 2022). Taken together, these studies are in line with the current results and emphasize the intricate multi-dimensional nature of vocabulary growth, especially in EFL settings.

AR's Effectiveness in Enhancing Vocabulary

The findings of the study showed that before the application of AR in learning vocabularies, the participants, consisting of 25 fourth-grade students showed moderate level of mastery of vocabularies as indicated by their average score on the pretest. When the AR intervention had concluded, word knowledge for the participants had increased significantly, with the post-test average going up to 83.20—falling within the rank of "Good" and "Very Good". This significant progress implies that AR was effective in boosting students' acquisition of English vocabulary, indicating it has the potential to become a useful pedagogical means for language learning for young learners. The results corroborate the claim that AR enhances not only learning but also learner engagement and motivation.

These findings re supported by previous studies. Chuang et al. (2022) noted that AR integration in language learning increased vocabulary learning as well as student enjoyment. Likewise, Tin-Chang et al., (2023) established that educational AR instruction brought a significant increase in students' vocabulary learning, providing evidence on its potential applicability in various learning environments. These results together add to a developing literature around AR as an effective and innovative model for vocabulary instruction, particularly with young learners in EFL settings.

Statistical Analysis & Interpretation

Statistical significance of the AR intervention was also confirmed with the results of the paired-samples t-test. The computed t value, 8.996, greatly surpassed the critical t value, 1.708 (df = 24, 50,05, one tailed), providing ample evidence to reject the null hypothesis. This shows that the difference between pre- test and post- test vocabulary scores was not a happening chancely but it was an effect of treatment. It could be inferred

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that that the utilization of Augmented Reality (AR) was significantly implemented to develop the mastery in vocabularies of the fifth grade students of elementary school. It is worth mentioning that these findings were in agreement with previous studies. Hudaya and Sadikin (2019) stressed the potential and fresh nature AR provides as an instructional approach for vocabulary learning in the 21st century, including for young learners who want to learn a new language. Agata et al., (2021) also indicated that media that utilized AR was effective for increasing students' engagement and enhancing learning outcomes. Likewise, Tyson (2021) showed that AR significantly aids in vocabulary learning and retention in comparison to traditional teaching approaches. Collectively these studies and our results illustrate the pedagogical benefit of AR in young children's language learning and justify its incorporation as a strategy for enhancing vocabulary instruction and learner involvement in the L2 elementary language program.

Limitations & Futture Research

Although this study revealed the value of AR for the vocabulary acquisition of elementary school students, there were several limitations. For one, technical accessibililty is still an issue, especially for underprivileged educational institutions where AR-capable devices and stable internet is not readily available. Second, teacher readiness and digital literacy skills is a key factor in the successful integration of AR; without proper training and pedagogical support the implementation may not achieve its full potential. Third, though the study demonstrated short-term gains for vocabulary knowledge it did not investigate retention of this knowledge.

In view of these limitations, in future, longitudinal studies should be used to investigate the long-term effect of AR on students' vocabulary retention. Moreover, the longer-term effects of AR on other language areas, such as reading comprehension and writing fluency, should be explored. Additionally, comparative studies of AR-based instruction with other digital technologies such as gamification and virtual reality (VR) could be helpful to determine more precise utility of technology in enhancing language acquisition. These insights not only contribute to our present understanding, but also provide guidance for educators and policy makers in terms of how to meaningfully and sustainably integrate AR into language curricula.

5. CONCLUSION

In this research, some of the major issues faced by the elementary English language learners in learning English vocabulary included pronunciation and spelling, meaning, contextual application, and connotation. Students had been of only moderate vocabulary skill before the treatment. But after Augmented Reality (AR) assisted-instruction was implemented, students' achievement increased dramatically, as demonstrated by the rise of average test scores from 61.56 to 83.20. Statistical analysis supported the reliability of this improvement and strong evidence showed that AR was useful to assist in vocabulary learning. These results are in line with previous studies and highlight the potential of AR for revolutionizing vocabulary teaching by providing an immersive and interactive learning environment. This study has potential implications for readers, learners and future researchers beyond its direct pedagogical applications. The results provide teachers, especially teachers at SD Negeri Jambon 2 the knowledge on how to integrate AR in teaching vocabularies and increasing their students motivation to learn. For learners, the to AR can be more interactive and fun, hopefully leading to a higher level of motivation and retention. For future research, the present study offers a methodological and empirical base for exploring AR's lasting effects as well as for applying AR in various language areas. Finally, this study contributes to the pedagogical debate around the language education and the implementation of AR as an innovative approach to language teaching.

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