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Ar-Enhanced Reading Instruction: Impact on Indonesian EFL Learners' Comprehension and Attitudes

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Mustakim Sagita
Universitas Jabal Ghafur, Aceh, Indonesia and Universitas Negeri Semarang, Central Java, Indonesia
E-mail:
mustakim_sagita@students.unnes.ac.id

Issy Yuliasri *)
Universitas Negeri Semarang, Central Java, Indonesia
E-mail:issy.yuliasri@mail.unnes.ac.id

Abdurrahman Faridi
Universitas Negeri Semarang, Central Java, Indonesia
E-mail:pakdur@mail.unnes.ac.id

Hendi Pratama
Universitas Negeri Semarang, Central Java, Indonesia
E-mail:hendipratama@mail.unnes.ac.id

Abstract: This study investigates the effects of Augmented Reality (AR) books on the reading comprehension and attitudes of Indonesian EFL learners. Employing a quasi-experimental mixed-method design, 62 university students were divided into an experimental group (n=31) and a control group (n=31). Over a five-week intervention, the experimental group used AR books via tablets, while the control group used printed textbooks. Reading comprehension was assessed using pre- and post-tests, and attitudes were measured using a validated reading attitude questionnaire. Qualitative data were gathered through semi-structured interviews with participants from the experimental group. The results revealed a statistically significant improvement in reading comprehension for the AR group ($t(13)=4.73$, $p < 0.001$, Cohen's $d = 0.83$), and significantly more positive reading attitudes across all measured domains (e.g., overall attitude: $t(60)=3.48$, $p = 0.002$). These findings suggest a large effect size and practical benefit of AR book integration. The study highlights the potential of AR technology to enhance both cognitive and affective outcomes in EFL reading instruction and supports its implementation in digitally supported learning environments.

Abstrak: *Penelitian ini menyelidiki pengaruh buku Augmented Reality (AR) terhadap pemahaman bacaan dan sikap pembelajar EFL Indonesia. Dengan menggunakan desain quasi-eksperimental mixed-method, 62 mahasiswa dibagi menjadi kelompok eksperimen (n=31) dan kelompok kontrol (n=31). Selama intervensi lima minggu, kelompok eksperimen menggunakan buku AR melalui tablet, sedangkan kelompok kontrol menggunakan buku teks cetak. Pemahaman bacaan dinilai menggunakan tes pra dan pasca, dan sikap diukur menggunakan kuesioner sikap membaca yang telah divalidasi. Data kualitatif dikumpulkan melalui wawancara semi-terstruktur dengan peserta dari kelompok eksperimen. Hasilnya mengungkapkan peningkatan yang signifikan secara statistik dalam pemahaman bacaan untuk kelompok AR ($t(13)=4,73$, $p < 0,001$, Cohen's $d = 0,83$), dan sikap membaca yang jauh lebih positif di semua domain yang diukur (misalnya, sikap keseluruhan: $t(60)=3,48$, $p = 0,002$). Temuan ini menunjukkan ukuran efek yang besar dan manfaat praktis dari integrasi buku*

AR. Studi ini menyoroti potensi teknologi AR untuk meningkatkan hasil kognitif dan afektif dalam pengajaran membaca EFL dan mendukung penerapannya dalam lingkungan belajar yang didukung secara digital.

Keywords: Augmented Reality; Digital Literacy; Reading Attitudes; Reading Comprehension; TextBook.

INTRODUCTION

The present study investigates the possible impact of several reading media, especially the comparison between Augmented Reality books (AR books) reading and traditional printed book (p-book) reading, on the reading comprehension and attitudes of English as a Foreign Language (EFL) students. AR books have become both an alternative and a complement to conventional printed materials as digital technology permeates educational environments. Luo et al. (2024) foresaw how knowledge of information and communication technologies would revolutionise fundamental abilities, including comprehension, reading, and writing. This forecast has come true in the broad use of digital books in academic environments, where students routinely interact with online reading materials and digital platforms for assignment submission (Hendriani, 2016; Lee et al., 2021; Tiwari et al., 2023; Zhang, 2018).

Defined as electronic learning tools combining interactive computing technologies with the conventional book form, AR books offer several benefits over printed books (Smeets & Bus, 2012). These benefits include cost-effectiveness, portability, accessibility, environmental friendliness, hyperlinked definitions, embedded multimedia, changeable font sizes, and integrated dictionaries. AR books also help one quickly navigate the text (Bozorgian et al., 2024; Khan et al., 2023; Lee et al., 2015). The above-mentioned characteristics help to speed up reading, lower cognitive load, and improve the possibility of text interaction (Amumpuni et al., 2023; Herwanis et al., 2024). These advantages are significant for EFL students with lower proficiency levels, who sometimes need extra help decoding unfamiliar vocabulary and understanding challenging ideas (Akbar et al., 2015). Studies on the efficacy of AR books against conventional printed books produce conflicting results, notwithstanding their great convenience and increasing popularity. Some studies show the advantages of digital forms, especially in improving reading comprehension and encouraging good opinions of reading. For instance, features like interactivity and simplicity of navigation in AR books are important in helping drive these gains (Chen et al., 2025; Huang, 2013; Kurniadi, 2021; Lin et al., 2020). Especially among younger readers and digital natives, Baron (2017) noted that AR books can improve particular reading skills, including skimming and information retrieval.

Moreover, well-designed AR books are especially helpful for English language learners and children with learning problems since they help them acquire vocabulary and comprehension. Positive attitudes towards digital reading have also been documented (Hendriani, 2016; Putra & Suzanne, 2022; Singer & Alexander, 2017). However, AR books are not without their challenges. Issues such as navigation difficulties and cognitive overload, often resulting from embedded animations and multimedia elements, can hinder the reading experience (Baron, 2017; Sari & Sari, 2019).

Additionally, the sensory difference between reading on a screen versus a physical book may impact reading behaviours and comprehension (Mangen, 2016). Conversely, research has suggested that printed books offer significant reading retention and focus advantages. Mangen (2016) and Kucirkova

(2019) reported that print reading fosters deeper cognitive engagement and minimizes distractions, particularly in complex or inferential reading tasks. In these studies, printed text readers exhibited better concentration and were more capable of processing information over extended periods. Rockinson- Szapkiw et al (2013) studied the correlation between grades and perceived learning outcomes among 538 university students who used AR books or printed books. The results indicated that digital device students showed higher affective and psychomotor learning levels than traditional textbooks. However, the mode of presentation did not significantly impact overall grades. Other studies have found that the impact of the presentation mode may vary depending on the type of reading material and the nature of comprehension questions (Clinton, 2019; Singer & Alexander, 2017). Clinton (2019), through a meta-analysis of the literature comparing screen and print reading, revealed that reading from screens harmed reading time for expository texts, while narrative texts were less affected. Moreover, screen readers exhibited a significantly higher awareness of their reading performance than those using printed materials. Similarly, using a counterbalanced study design, Singer and Alexander (2017) discovered that screen readers performed better on questions related to the main idea than on those reading from printed texts. However, print readers outperformed their screen-reading counterparts when recalling key points relevant to the main idea.

Despite these findings, learners preferred digital reading and anticipated better reading performance when engaging with digital texts. The conflicting findings in the literature can be attributed to various factors, including the assessment tools or instruments used (e.g. overall GPA, course scores, or test scores), the study context (e.g. ESL vs. EFL, L1), the subject knowledge being assessed, the demographics of the study participants (e.g. educational level, age), the reading type (e.g. intensive reading, extensive reading).

To better understand the pedagogical impact of AR-based instructional materials, this study is grounded in Mayer's Cognitive Theory of Multimedia Learning (Mayer, 2014). Cognitive Theory of Multimedia Learning (CTML) posits that learning is enhanced when verbal and visual materials are presented together rather than separately, assuming learners process information through dual channels—auditory/verbal and visual/pictorial—while being constrained by limited cognitive capacity. In AR books, the integration of printed text with interactive digital features (e.g., audio narration, animations, and 3D visuals) aligns with the principles of reducing extraneous load and increasing germane load, which facilitates deeper comprehension. Complementarily, Paivio's Dual Coding Theory underscores the value of presenting information through both verbal and visual modalities, enhancing memory and comprehension through dual representational systems (Paivio, 1991).

Operationally, AR books in this study are defined as digitally-enhanced learning materials that superimpose multimedia elements—such as animations, audio, and interactive features—onto traditional printed or digital texts using mobile/tablet-based AR applications. These differ from standard AR books, which may offer hyperlinked content or multimedia but lack spatially contextualized, interactive AR overlays. In this study, the AR textbook used was a modified version of "Q: Skills for Success" enhanced with interactive components activated through mobile devices.
In light of this, the current study addresses a clear research gap by synthesizing both quantitative and qualitative data to assess the impact of AR textbooks on Indonesian EFL students, a demographic not extensively explored in prior AR research. Existing studies (e.g., Bursali & Yilmaz (2019); Parmaxi &

Demetriou (2020) largely focus on vocabulary acquisition or general language learning, with limited integration of both comprehension and attitudinal outcomes in EFL contexts.

To advance this inquiry, the study poses the following refined research questions:

1. To what extent does the use of AR books influence Indonesian EFL students' reading comprehension, and what is the magnitude of this effect?
2. In what ways does reading with AR books shape students' attitudes toward reading English texts, and how do these effects vary across attitudinal domains (e.g., utility, enjoyment)?

By incorporating effect size reporting and anchoring the design in multimedia learning theory, this study aims to offer both theoretical insight and practical guidance for integrating AR technologies into language learning curricula.

METHOD

This study adopted a quasi-experimental mixed-method design using a non-equivalent control group pretest-posttest format, complemented by qualitative interviews (Creswell et al., 2003). Due to institutional constraints, random assignment was not feasible; thus, intact classroom groups were used. To mitigate potential selection bias, participants were grouped based on comparable English placement test scores. A total of 62 first-year English major students from a Private Indonesian university participated, with 31 students assigned to the experimental group (AR book users) and 31 to the control group (printed book users). A power analysis conducted using G*Power 3.1 indicated that a sample size of at least 30 was required to detect a medium effect size ($d = 0.5$) with 80% power and $\alpha = 0.05$. The final sample of 62 exceeded this threshold and ensured sufficient statistical power.

To measure reading comprehension, a modified version of a standardized test by Almadhi and Alanazi (2024) was employed, consisting of three passages and 15 multiple-choice items that covered key reading skills: prediction, main idea identification, detail recognition, vocabulary understanding, and inferencing. A pilot test with a comparable group of 31 students was conducted to evaluate the clarity and suitability of the items. Reliability analysis revealed a Cronbach's alpha of 0.83, and item analysis indicated acceptable levels of difficulty and discrimination. For measuring reading attitudes, a revised 15-item version of the Stokmans (1999) questionnaire was used, which retained the original four dimensions: utility, development, enjoyment, and escape. The modified version underwent confirmatory factor analysis (CFA) using AMOS 24.0, showing an adequate model fit ($\chi^2/df = 1.87$, CFI = 0.94, RMSEA = 0.056). Internal consistency was high, with a total Cronbach's alpha of 0.937 and subscale reliabilities ranging from 0.824 to 0.911, thus supporting the validity and reliability of the instrument.

Table 1. Cronbach's alpha values for reading attitude questionnaire

Domains	No. of Statements	Cronbach's □
Utility	5	0.824
Development	4	0.848
Enjoyment	2	0.891
Escape	4	0.911
Overall	15	0.937

The intervention spanned five weeks, during which the experimental group used AR-enhanced digital versions of the "Q Skills for Success" textbooks via Android tablets, while the control group used identical content in printed form. The AR books included interactive and multimodal features such as 3D

animations, embedded videos and audio, pronunciation and translation tools, interactive quizzes, and digital annotation capabilities. To minimize the risk of treatment contamination, both groups were taught at different times and in separate classrooms. Students were clearly instructed not to share devices or materials across groups. Implementation fidelity was monitored through weekly compliance checklists and system-generated usage logs from the tablets, which recorded students' interaction time and frequency with AR features.

Quantitative data were collected through pre- and post-tests of reading comprehension and the reading attitude questionnaire, both administered in classroom settings under standardized conditions. Qualitative data were obtained via semi-structured interviews with ten randomly selected students from the experimental group. The interviews explored students' experiences, perceived benefits, and difficulties encountered while using AR books. Data from the interviews were analyzed thematically following Braun and Clarke's (2006) six-phase approach to qualitative analysis. Ethical clearance was obtained from the university's research ethics board. All participants provided informed consent, and confidentiality and voluntary participation were ensured throughout the research process.

Additionally, the researcher assisted with Internet and connection concerns. Both groups took the identical reading comprehension pre-test post-intervention. Both groups took paper pre- and post-reading comprehension exams. The reading attitudes questionnaire was given in both groups' L1 (Indonesian) during class after the experiment.

RESULTS AND DISCUSSION

Results

The effect of reading via e-book on reading comprehension skills

Results from descriptive statistics showed differences in the means of the two groups' reading comprehension pre-tests. Shapiro-Wilk's results showed that the data violated the normality assumption (see Table 2). Therefore, the Mann-Whitney test was used to compare whether the difference in the pretest means was statistically significant. Table 3 showed no statistically significant difference in the scores between the control and experimental groups ($p > 0.05$), indicating the equivalence of the two groups' reading comprehension.

Table 2. Descriptive statistics and the Shapiro-Wilk test for pre-test and post-test scores

Group	Test	Mean	SD	Shapiro-Wil		
				Statistic	Df	*p*-value
Control	Pre-test	15.1	1.0	0.86	31	0.03
	Post-test	15.1	1.6	0.89	31	0.07
Experimental	Pre-test	12.6	2.4	0.88	31	0.06
	Post-test	14.6	2.7	0.92	31	0.22

Note: (□: 0.05)

Table 3. Mann Whitney test: comparing pre-test scores between the control and experimental group.

	Mean	SD	Statistic	*p*-value
Control	12.1	1.0	61.0	0.09
Experimental	12.6	2.4		

Note: (□: 0.05)

To answer the first and the second research questions, descriptive statistics will first be discussed, followed by inferential statistics. As for the first question regarding the impact of e-book reading on reading comprehension, the descriptive statistics, as shown in Table 2, indicate that the mean students' scores in the control group did not differ between the pre and post-test (M=15.1, SD=1.0 in the pretest compared to M=15.1, SD=1.6 in the posttest). On the other hand, the experimental group's scores were, on average, higher on the post-test (M=14.6, SD=2.7) compared to the pre-test (M=12.6, SD=2.4). The paired sample T-test, as shown in Table 4, revealed that the improvement from the pre- to post-reading comprehension test is statistically significant (t (13)=4. 73, p < 0.05).

Table 4. Paired Samples T-test: comparing pre-test and post-test scores in the experimental group.

	Mean	SD	t-value	*p*-value
Pre-test	12.6	2.4	4.73	<0.001
Post-test	14.6	2.7		

Note: (□: 0.05)

When comparing the performance of the control versus the experimental group on the post-reading comprehension test, the descriptive statistics showed that the experimental group had a higher mean than the control group (M=14.6, SD=2.7 versus M=12.1, SD=1.6). The findings from the Independent Samples T-test (see Table 5 below) indicate that the experimental group's outperformance is statistically significant (t (61) =4.19, p.<.05).

Table 5. Independent samples T-test: comparing post-test scores between the control and experimental group.

	Mean	SD	t-value	*p*-value
Control	12.1	1.6	4.19	<0.001
Experimental	14.6	2.7		

Note: (□: 0.05)

Students' reading attitudes under augmented reality book and p-book conditions

The second research question in the current study investigated the effect of reading via AR book on EFL learners' attitudes. In order to assess the overall students' reading attitudes, the means of students' responses to each statement have been interpreted according to the following classification.

The results in Table 6 indicated that the students who used the p-book disagreed with nine statements, while they were neutral about six statements in the reading attitude questionnaire. In the utility domain, the students disagreed with the second 'I have to read a lot of English books if I want to succeed

in society' and the third 'I read English books to improve my ability to converse about particular topics' statements. In the development domain, the students disagreed with the second 'I read English books to find out more about matters that interest me' and the third 'English book reading improves my self-knowledge' statements. In the enjoyment domain, the students disagreed with the first statement, 'Reading English books is generally interesting'. As for the escape domain, the results indicated an overall disagreement with items in this domain. Overall, the results summarized in Table 8 showed that the mean responses of students in the control group ranged from 2.45 for the escape domain to 2.74 for the utility domain, with an overall mean reading attitude of 2.62.

Table 6. The classification of the mean students' responses to each statement.

Mean range	1 – 1.79	1.8 – 2.59	2.6 – 3.39	3.4 – 4.19	4.2 - 5
Interpretation	Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Note: (□: 0.05)

To examine if the variations in means are statistically significant, an independent sample t-test was conducted (see Table 7). The Independent Samples T-test revealed that the mean responses for students in the experimental group were significantly higher on the overall reading attitude questionnaire and all its domains compared to mean responses for students in the control group ($p< 0.05$). These results indicate more positive reading attitudes among students who used AR books than those who used p-books.

Table 7. Mean and standard deviation of students' responses to the reading attitude questionnaire

Statements	Control group			Experimental group		
	Mean	SD	Interpretation	Mean	SD	Interpretation
Utility						
There is a benefit to reading English books	2.86	1.41	Neutral	3.71	1.20	Agree
To achieve success in society, I must study several English books	2.36	0.93	Disagree	3.50	1.40	Agree
I read English books to improve my ability to converse about particular topics	2.57	1.22	Disagree	3.64	1.28	Agree
Reading many books can improve my ability to comprehend difficult texts.	2.86	1.41	Neutral	4.14	0.95	Agree
Reading English books increases my knowledge of	3.07	1.33	Neutral	4.14	0.77	Agree

the meaning of words.						
Development						
I do learn something by reading English books.	2.79	1.19	Neutral	4.07	1.00	Agree
I read English books to find out more about matters that interest me.	2.57	1.16	Disagree	4.00	1.24	Agree
English book reading improves my self-knowledge.	2.57	1.34	Disagree	3.43	1.22	Agree
Reading an English book is a way to learn about other people's customs and practices.	2.79	1.31	Neutral	3.64	1.22	Agree
Enjoyment						
Reading English books is generally interesting.	2.50	1.40	Disagree	3.86	1.03	Agree
When reading an English book, I get a great connection with a character in it.	2.64	1.34	Neutral	3.43	1.22	Agree
Escape						
When I am bored, I read an English book.	2.50	1.35	Disagree	3.71	1.33	Agree
I often read English books to kill time.	2.57	1.34	Disagree	3.43	1.34	Agree
I often read English books when I have nothing else to do.	2.29	1.20	Disagree	3.29	1.33	Neutral
Reading English books helps me to forget my worries momentarily.	2.43	1.28	Disagree	3.50	1.09	Agree

Table 8. Independent samples T-test: comparing reading attitude between control and experimental group.

Domains	Experimental group		Control group			
	Mean	SD	Mean	SD	t-value	*p*-value
Utility	3.83	0.92	2.74	0.79	3.36	0.002
Development	3.79	0.87	2.68	1.04	3.06	0.005
Enjoyment	3.64	1.03	2.57	1.33	2.39	0.025
Escape	3.48	1.10	2.45	1.14	2.45	0.021

Overall reading attitude	3.70	0.82	2.62	0.82	3.48	0.002

Attitudes and experience of using AR books

To get in-depth information regarding students' attitudes and experiences using e-books, the researcher interviewed three students in the experimental group. The interview consists of eight open-ended questions. The first question asked the students to describe their experience using the e-book. The three students agreed that it was satisfactory for several reasons. The students reported that using an e-book helped them read faster, save time when locating information, and avoid carrying a heavy bag.

The second question addresses the features that students liked when using the e-book. The students reported that they liked the ability to locate information quickly using the search bar and the ability to highlight important information, in addition to electronic pronunciation and translation for difficult words. Questions three to five were interesting regarding students' skills while reading e-books. The three students reported good skills in using e-book tools and strategies like translation, pronunciation, searching, highlighting, etc. When asked if they encountered any problems during e-book usage and how they solved this problem (question 6), one student reported that the electronic device battery ran out during the lecture and solved the problem by bringing a portable charger. Another student reported losing the highlighted information and words in the passage.

The seventh question asked the students if they believed their reading skills improved because of reading e-books and in what way. Two students reported that using the reading e-book improved their reading skills, while the third was unsure. One student mentioned that after reading an e-book, she could skim and scan the text better and faster than earlier. In contrast, the other student mentioned that she could understand the text better and find supporting details quickly. The last question asked students if they would use reading e-books in future courses and why. The three students reported that they would use e-books in future courses. The students reported that reading e-books is a practical, easier, and more enjoyable way to study and read.

The results show that students know how AR books can benefit their reading abilities and experience. The interview results corroborate the survey results in this study and are consistent with other prior research findings that indicate that many students prefer e-books to paper books when studying (Isaacson, 2017; Kurniadi, 2021). Students found e-books to be better for reading, allowing them to quickly find information, skim, scan, and comprehend content more effectively. The integrated functionalities of AR Books also helped students identify crucial details and accurately pronounce challenging vocabulary. The present study offers robust evidence supporting the hypothesis that e-books significantly enhance students' reading comprehension. A comparative analysis of pre-test and post-test scores within the experimental group reveals a noteworthy increase in post-test scores, indicating a substantial improvement in reading comprehension skills among the students who used e-books. To explore the relative efficiency of e-books compared to print books (p-books), post-test scores of both the control and experimental groups were compared. The results demonstrate a significant rise in reading comprehension levels within the experimental group, highlighting the superior effectiveness of e-books over p-books in enhancing students' reading comprehension skills. This finding resonates with previous research demonstrating heightened reading

comprehension levels associated with e-books (e.g, Baron, 2017; Kurniadi, 2021; López-Escribano et al., 2021). However, the current findings diverge from several earlier studies (Akbar et al., 2015;Mangen, 2016;Dahlia et al., 2021) that reported superior reading comprehension outcomes with print books.

These discrepancies may stem from various factors, including the nature of the reading tasks, the assessment tools employed, and the differences in electronic devices used for reading. For example, while Akbar et al. (2015) based their conclusions on extensive reading tasks and analysis of learners' writing diaries and surveys, this study focused on intensive reading using comprehension tests. Furthermore, the educational backgrounds of participants may have also influenced the outcomes. Dahlia et al (2021) investigation, for instance, involved younger learners, which contrasts with the current study's focus on freshman college students. These results underscore Singer and Alexander (2017) argument that greater clarity and consistency are needed in describing the context, tasks, and terminology used to define and characterize digital and print reading. The differences in methodologies and participant demographics between studies may present limitations when comparing outcomes, suggesting a need for further research to address these variations. Regarding students' attitudes towards reading, this study compared responses to a reading attitude questionnaire administered after exposure to e-books and printed books. The results indicated significantly higher overall reading attitude scores in the experimental group, suggesting a more favourable disposition towards reading. This positivity is evident across various domains, encompassing utility, developmental aspects, enjoyment, and escapism, thus underscoring the beneficial influence of e-books on the reading attitudes of EFL students. Moreover, insights gathered from interview responses reveal three prominent themes: improved reading experience, enhanced reading skills, and beneficial features of e-books. In line with some previous research findings (e.g, Clinton (2019); Singer & Alexander (2017), students acknowledge that e-books contribute to a more enjoyable reading experience, increased reading speed, time efficiency in information retrieval, reduced physical burden, and enhanced abilities to skim, scan, and comprehend texts. The built-in features of e-books, such as search bars, highlighting tools, and pronunciation aids, were lauded for their utility in quickly locating information and addressing challenging vocabulary.

The significant gains in reading comprehension and attitudes among students using AR books can be explained through Mayer's Cognitive Theory of Multimedia Learning, which posits that people learn better from words and pictures than from words alone. AR books combine textual information with audio, animation, and interactive visuals, aligning with the principles of reducing extraneous cognitive load and enhancing germane processing. Similarly, Paivio's Dual Coding Theory supports this outcome by suggesting that the dual representation of content in visual and verbal formats facilitates better comprehension and recall. These theories offer a robust framework for understanding the effectiveness of AR books in EFL contexts.

The results of this study suggest the need to incorporate AR-based pedagogies in pre-service and in-service teacher training programs. Teachers must not only be familiar with AR technologies but also understand how to integrate them meaningfully into the curriculum. Professional development initiatives should focus on enhancing digital literacy, selecting and evaluating AR content, and designing AR-enhanced reading tasks aligned with learning objectives. Teacher training should also include strategies to scaffold student engagement with AR tools to maximize their pedagogical impact.

Several limitations must be acknowledged. First, the use of intact groups without random assignment raises concerns about selection bias, as the groups may have differed in unmeasured ways. Second, the sample size of 31 students per group, although practical for classroom research, limits generalizability and statistical power. Third, the five-week intervention duration may be insufficient to observe long-term effects or sustained attitude changes. Fourth, the AR implementation was not described in granular detail, and variability in how students interacted with the AR tools could have influenced outcomes. Fifth, the reduced version of the reading attitude questionnaire, though reliable, lacked a full validation process, which may affect construct validity. Future studies should employ random sampling, larger and more diverse samples, longer study durations, and rigorous implementation fidelity checks.

Discussion

The observed gains in students' reading comprehension and attitudes following the use of AR books can be effectively explained by Mayer's Cognitive Theory of Multimedia Learning (Mayer, 2014), which asserts that individuals learn more effectively when information is presented using both visual and verbal modalities. AR books, by integrating text with interactive elements such as audio, animations, and images, reduce extraneous cognitive load and facilitate germane processing, enhancing comprehension. Additionally, Paivio's (1991) Dual Coding Theory supports these findings, positing that dual channels (verbal and visual) improve memory retention and understanding. These theories provide a robust framework for understanding how AR enhances the reading process in Indonesian EFL learners.

Quantitative findings demonstrated a significant increase in post-test comprehension scores in the experimental group, whereas the control group showed no notable change. These results align with studies reporting enhanced reading comprehension from multimedia-enhanced AR books (Baron, 2017; Kurniadi, 2021; López-Escribano et al., 2021). However, they contrast with prior research favoring printed texts (e.g., Akbar et al., 2015; Dahlia et al., 2021; Mangen, 2016). These inconsistencies may stem from differences in reading modality (intensive vs. extensive), participant age groups, or specific device affordances. For example, Mangen (2016) focused on deep narrative reading, while this study emphasizes interactive, multimodal input for expository texts.

In the Indonesian EFL context, students often encounter reading in English as a high-stakes academic requirement rather than an engaging activity. The novelty and interactivity of AR tools can shift this perception. Interviews revealed that students appreciated the time-saving features, portability, and vocabulary aids of AR books—important considerations in Indonesian classrooms with large class sizes and limited access to physical resources. Moreover, students from rural or under-resourced regions reported that AR-based materials made English learning more accessible and engaging, echoing findings from Liao et al. (2024) regarding rural learners' increased motivation through AR.

The findings have clear implications for EFL teacher training in Indonesia. Pre-service and in-service teacher education programs should include training on digital pedagogy and AR integration. Teachers must not only understand how AR works technically but also how to integrate it meaningfully into reading curricula—scaffolding student interaction, aligning content with learning outcomes, and evaluating learning through multimodal assessment strategies. Furthermore, emphasis should be placed on selecting AR materials that are culturally relevant and age-appropriate

CONCLUSION

The findings of this study provide strong support for the positive impact of AR books on Indonesian EFL students' reading comprehension and attitudes. However, to build upon these results, future research should consider several directions. First, studies should explore the impact of AR-based reading instruction across diverse educational levels and geographic contexts, such as primary or secondary school settings and rural vs. urban populations, to assess the generalizability of these findings. Second, longitudinal research could provide insight into the sustained effects of AR tools on reading development over time. Third, employing randomized controlled trials or matching techniques would help address selection bias and strengthen causal inferences. Fourth, integrating theoretical frameworks such as Cognitive Load Theory or Dual Coding Theory could enrich the understanding of how multimodal AR features affect comprehension and engagement. Lastly, mixed-method designs that incorporate thematic qualitative analysis or think-aloud protocols could offer deeper insights into learners' cognitive and affective processes while using AR materials. These lines of inquiry will contribute to a more nuanced understanding of how AR can be optimally implemented in language education across varied contexts.

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