

PAPER

The Impact of Augmented Reality Storybooks on Children's Reading Comprehension and Motivation

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ABSTRACT

While existing literature extensively explores the application of augmented reality (AR) technology in science, technology, engineering, and mathematics (STEM) fields and higher education, research on its use in children's reading remains relatively limited. This research gap urgently needs to be addressed, particularly in understanding how AR can enhance children's reading comprehension, story retelling, and reading motivation. To address this gap, this study examined the effects of AR Chinese picture storybooks on second-grade students' reading comprehension, story retelling, and reading motivation. A quasi-experimental design was employed with 60 second-grade students from a primary school in central China, where 30 students used AR storybooks and 30 used traditional paper storybooks. The results indicated that students who used AR storybooks demonstrated better reading comprehension, particularly implicit comprehension, than those who used paper storybooks. However, there was no significant difference between the two groups in explicit comprehension. Additionally, the AR storybook group outperformed the paper storybook group in both story retelling and reading motivation. These findings suggest that AR technology can create more interactive and immersive reading experiences, positioning AR as a promising tool for enhancing literacy development in young learners.

KEYWORDS

augmented reality (AR), multimedia and virtual environments, M-learning applications, interactive mobile technology, learning motivation

1 INTRODUCTION

Reading is the process of acquiring information and meaning through words or symbols. It goes beyond recognising and understanding the surface meaning of words to include deeper understanding and critical thinking about the meaning behind the words [1]. Early reading plays an important role in the development of children's literacy, as it not only contributes to the development of language and cognitive skills but also stimulates imagination and creativity and promotes concentration and critical thinking [2]. In addition, reading habits profoundly impact lifelong

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learning and academic success while encouraging the development of emotional and social skills and providing a solid foundation for a child's overall development [3]. Therefore, studies have shown that children should be encouraged to read early to enrich their vocabulary, develop their storytelling skills, and ultimately achieve independent reading [4].

Stories and picture books play an important role in children's reading, particularly regarding literacy, motivation, and cognition [5]. First, through exposure to rich and varied plots and language expressions, children can improve their literary level and expand their vocabulary and language sense [6]. Moreover, interesting stories stimulate their motivation to read and develop a lasting interest. Stories' plot reasoning and character analysis contribute to children's cognitive development and enhance their comprehension and imagination [7]. Therefore, the main focus of educational researchers and teachers is on how to improve children's reading skills effectively.

However, limited vocabulary and language comprehension make it difficult for children to fully comprehend stories, leading to poor or even reluctant reading [8]. In addition, a lack of attention and concentration makes it difficult for them to maintain focus while reading for long periods, affecting their reading fluency and confidence [9]. To address these issues, many researchers have turned to multimedia technologies to support children's reading, including e-books, interactive e-books, and multimodal e-books [10]. These e-books are characterised by rich multimedia elements and interactive features, such as animations, sound effects, videos, and voice-overs, which enrich the reading experience and capture children's attention [11]. In addition, mobile devices and interactive components such as touch-screen operation, games, and human-computer interaction are incorporated to encourage children's active participation, exploration, and learning, thereby improving their comprehension and fostering a deeper interest in reading [12], [13]. Conversely, some researchers have suggested that reading e-books may divert children's attention and increase their cognitive load due to various distractions, thus reducing the effectiveness of reading [14]. In contrast, reading a paper book provides a simpler, distraction-free environment that helps children concentrate better [15].

Recent technological advancements in augmented reality (AR) have significantly expanded its applications in educational settings, transforming traditional learning environments into interactive and dynamic experiences [16], [17]. Incorporating AR into storybooks can offer a potential solution to the above problems, as they are a digital reading experience that combines AR technology with the traditional storybook format [18]. Such storybooks overlay virtual digital content onto the real world through mobile devices or special AR glasses, allowing readers to interact with scenes, characters, and objects in the story [19]. At the same time, AR storybooks typically include rich visual effects, animations, sound effects, and interactive elements, providing readers with an immersive reading experience that enhances comprehension and engagement [20]. The potential benefits of AR technology in children's reading comprehension, story retelling, and reading motivation lie in its ability to provide a multi-sensory learning experience that can cater to different learning styles, reduce cognitive load, and maintain engagement through interactive and engaging content.

This study is underpinned by several theoretical frameworks. The Cognitive Theory of Multimedia Learning (CTML) posits that people learn more effectively from words and pictures than from words alone, as it leverages both the verbal and visual channels of processing information [21]. This theory suggests that AR storybooks can enhance children's reading comprehension and engagement by integrating text with rich multimedia elements. Additionally, Piaget's stages of cognitive development highlight the importance of concrete operational stages (ages seven to 11), where children begin to think logically about concrete events but still struggle with

abstract concepts [22]. AR can provide concrete visualisations of abstract concepts within stories, thereby aiding comprehension and retention.

Many studies have demonstrated the effectiveness of integrating AR into teaching and learning [23], [24], [25], [26]. For example, Waskito et al. [25] developed AR applications that improved student engagement and comprehension through interactive 3D objects in engineering mechanics. Beltozar-Clemente et al. [27] highlighted that incorporating a mobile AR application into the teaching process has a notable impact on the learning experience of primary school students, particularly in astronomy. A study by Lai and Chang [28] found that integrating AR applications into English vocabulary learning can significantly increase motivation and learning outcomes for first-grade students. In addition, a study by Liu et al. [29] found that the use of AR in physics education significantly improved students' knowledge improvement. They also found that students who used AR experienced the lowest cognitive load and had positive attitudes towards AR. These findings support the potential of AR to enhance educational outcomes across various disciplines, suggesting its broader application could yield significant benefits.

Following a review of the literature, this study identified several significant research gaps. Although a considerable amount of work has been done in previous studies to investigate the effectiveness of integrating AR technology into teaching and learning, these studies have primarily focused on the STEM disciplines. This focus on STEM subjects, while important, has resulted in a lack of research on the potential use of AR technology in reading education, especially for young children. The gap is significant because early reading skills are foundational for lifelong learning, and enhancing these skills through innovative technologies like AR could have long-lasting educational benefits. Moreover, existing research has predominantly concentrated on higher education levels, neglecting the unique needs and developmental stages of young children. Addressing this gap is crucial as young learners may interact with AR technology differently than adult learners, necessitating tailored research to understand its impact on their reading comprehension, story retelling, and motivation. Through this focus, this study not only enriches the research scope of existing AR educational applications but also provides an important reference for the future application of AR technology in early reading education.

Several studies have explored the impact of AR in reading education, with varying results. For instance, Direkçi [18] conducted a study and found that students' reading comprehension was significantly better when using AR storybooks than traditional storybooks. However, Tobar-Muñoz et al. [30] reported no significant difference in reading comprehension between AR and traditional storybooks. Liu et al. [31] demonstrated that AR notably affected students' story-retelling abilities, particularly in their understanding of the story plot. In contrast, the study conducted by Danaei et al. [32] found no significant differences between AR and traditional storybooks in terms of story-retelling, specifically regarding characters and themes. Given these conflicting results, our study is unique in that it investigates the effectiveness of AR storybooks on children's reading comprehension, story retelling, and reading motivation. Based on this, this study formulated the following research questions to investigate the effectiveness of AR storybooks in enhancing children's reading:

1. What is the effect of using AR storybooks on primary school students' reading comprehension scores compared to traditional paper-based storybooks?
2. How does the use of AR storybooks impact primary school students' Story Retelling scores compared to traditional paper-based storybooks?
3. What is the influence of AR storybooks on primary school students' motivation to read compared to paper storybooks?

2 MATERIALS AND METHODS

2.1 Participants

Sixty second-grade students from a primary school in a city in central China selected by convenience sampling participated in this experiment. The 60 subjects included 28 girls and 32 boys aged seven to eight years. The two classes were randomly assigned to an experimental group (reading with AR storybooks) and a control group (reading with paper books) of 30 students each. These two classes shared the same reading teacher and were taught the same reading content before the experiment. Before the experiment, the researcher surveyed the teachers and subjects and found that all the children had yet to use an AR storybook or technology. In this study, each subject was given the same mobile phone model for the experiment.

2.2 Picture books

Two Chinese picture books were chosen as reading materials for this study, including *Who's in It* and *If I Had Wings*. The researcher first conducted a pilot study with second-grade students and found that the difficulty level of these picture books was appropriate for this age group. It should be noted that the students who took part in the pilot study did not participate in the formal experiment. To obtain the baseline of the participants' reading level, the researcher used *Who's Inside* as pre-test reading material to determine the student's level of reading comprehension and story retelling. The other picture books were used as reading materials for the formal experiment: storybooks with complete plots. The researcher created AR effects for these two picture books.

Students in the experimental group read these picture books using the same mobile phone model, while students in the second control group used the paper version of the picture books. The AR effects were created using an app provided by the publisher. Participants in the experimental group could scan the page to access the corresponding AR content. As shown in Figure 1, students in the experimental group can interact with the story content by clicking, touching, and zooming in and out.



Fig. 1. Comparison between the paper version and the AR picture book (left: pictures in the paper book; right: the AR effect of the same page)

2.3 Data collection tools

The reading comprehension test used the structure proposed in the study by Paris and Paris [33], which states that subjects should be tested on explicit, implicit, and inferential questions when testing reading comprehension. However, the inferential comprehension dimension was excluded from this study because of the limited cognitive abilities of second graders. Therefore, this study developed a test with eight questions for each of the two picture books used in the experiment. The explicit questions were four multiple-choice questions that tested the participants' comprehension of overt information, such as the main characters, the story's background, and the specific plot. The implicit questions, on the other hand, were open-ended questions that tested the students' deeper understanding of the story, such as explaining the causes and consequences of the story, explaining the story's theme, and summarising the story's ending. Both tests had the same structure and wording. Each explicit question is scored one point, and each implicit question is scored 2 points (0 points for an incorrect answer, 1 point for a partially correct answer, and 2 points for a completely accurate answer), so the reading comprehension test has a score range of 0 to 12 points. The higher the score, the better the participant's reading comprehension. Two experienced teachers and content experts administered the I-CVI to the two sets of tests with scores of 0.92 and 0.95, indicating that these tests have high content validity.

The story retelling test was adapted from the Liu et al. [31] study and had four dimensions: setting, theme, plot, and ending. Participants were given four pictures from picture books to help them retell the story, and the text was removed from these pictures. During the test, an experienced teacher guided each participant individually through the test, and their retellings were audio-recorded. After completing the test, two experienced teachers listened to the recordings and scored the participants according to the coding rubric designed for this study. Given the age of the participants, this study also developed a guide sheet for the teachers to use so that they could provide the participants with guiding prompts, as needed, to help them retell as much of the stories as possible. Each picture is scored 8 points, 2 points for each of the four dimensions, and the scoring criteria are as follows: 0 points for an incorrect answer, 1 point for a partially correct answer, and 2 points for a completely correct answer. The retelling test is worth a total of 32 points. The higher the score, the better the student's retelling ability. Two teachers carried out the inter-rater reliability test; the results were 0.95.

The reading motivation scale used in this study was adapted from the learning motivation scale [34], which consists of four dimensions: 1) attention, 2) relevance, 3) confidence, and 4) satisfaction. The scale from Lin and Wang's [34] study was used because the learning motivation scale was developed by translating the IMMS into Chinese and adapting the items. The original scale had 30 questions, and considering the limited working memory of students, this study adapted the number of questions to 12, and each dimension contains three questions, with a reliability coefficient of Cronbach's α of 0.93.

2.4 Research design

A quantitative approach was employed in this study using a quasi-experimental design with the pre- and post-test control group experiment for data collection. During the two-week experiment, all participants read in their daily reading class.

Each reading session lasted 40 minutes, and participants in the experimental group used AR storybooks while students in the control group used paper storybooks. The first week began with a pre-story comprehension test, a pre-story retelling test, and a pre-reading motivation test to establish a baseline for the students. Formal reading started in the second week, with the teacher first spending 15 minutes introducing the storybook and explaining how to use the AR storybook. Then the experimental and control groups read using the AR storybook and the paper storybook, respectively. Following the reading, a post-story comprehension test, a post-story retelling test, and a post-reading motivation test were administered, as shown in Figure 2.

Before the experiment started, informed consent was obtained from the participant's parents or guardians. Ethics approval for this study was also obtained from the author's university. Participants were told that they could withdraw from the experiment without consequence.

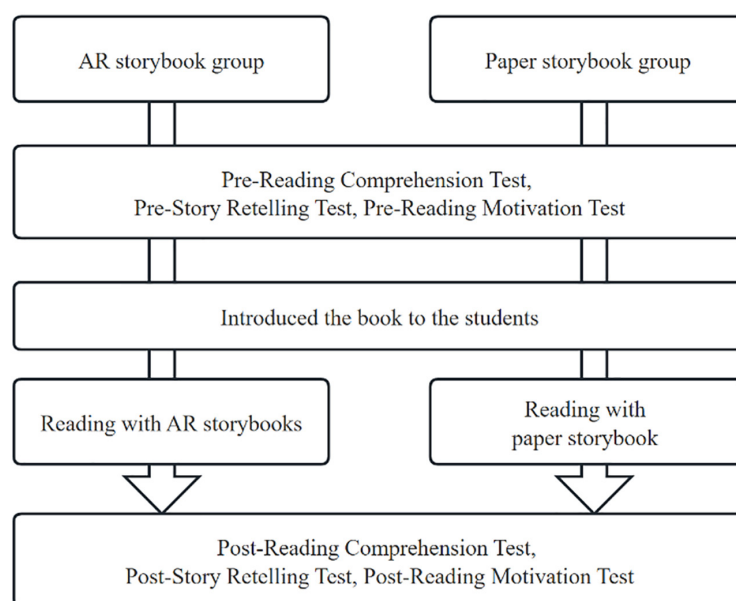


Fig. 2. Experimental procedure

3 RESULTS

This study used SPSS 25 to examine whether there was a significant difference in reading comprehension, story retelling, and reading motivation between the experimental group using AR storybooks and the control group using paper storybooks. Pre-test data was collected using *Who's in It* as the pre-test reading material. *If I Had Wings* was used as the experimental reading material to collect post-test data. To control for pre-existing group differences in the pre-test and reduce error variance, ANCOVA analyses were employed to determine whether there was a significant difference between the two groups of students in this study.

3.1 Results of the reading comprehension test

ANCOVA was used after it was determined that the results of the homogeneity of regression slopes ($F = 0.01, p > 0.05$) and Levene's test for homogeneity of variances ($F = 0.842, p > 0.05$) did not violate the assumptions for the use of ANCOVA. As shown

in Table 1, the reading comprehension scores of students who used AR storybooks (adjusted mean = 9.71) outperformed those who used paper storybooks (adjusted mean = 8.22), with $F = 39.521$, $p < 0.001$. The results ($\eta^2 = 0.41$) indicate that AR storybooks have a large effect on students' reading comprehension test scores.

Table 1. ANCOVA result of the reading comprehension

Group	N	Mean	S.D.	Adjusted Mean	F	η^2
AR storybook	30	9.77	0.935	9.71	$F = 39.521$, $p < 0.001$	0.41
Paper storybook	30	8.17	1.117	8.22		

In order to further investigate students' differences in explicit and implicit comprehension, this study also conducted ANCOVA analyses for both dimensions. For the explicit comprehension dimension, the results of homogeneity of regression slopes ($F = 0.331$, $p > 0.05$) and Levene's test for homogeneity of variance ($F = 1.317$, $p > 0.05$) indicated that the assumptions for using ANCOVA were fulfilled. The results, shown in Table 2, showed that there was no significant difference in explicit comprehension between the two groups of students ($F = 0.134$, $p > 0.05$, $\eta^2 = 0.002$), with an adjusted mean of 3.39 for the AR storybook group and 3.44 for the paper storybook group.

For the implicit comprehension dimension, after examining the homogeneity of regression slopes ($F = 0.001$, $p > 0.05$) and Levene's test for homogeneity of variance ($F = 0.074$, $p > 0.05$), it was determined that the assumptions for the use of ANCOVA were met and ANCOVA was used. As shown in Table 2, there was a significant difference in implicit comprehension scores between the two groups ($F = 56.99$, $p < 0.05$), with students using AR storybooks achieving significantly higher scores (adjusted mean = 6.31) than those using paper storybooks (adjusted mean = 4.79). The results ($\eta^2 = 0.50$) suggested that AR storybooks had a large effect on students' implicit comprehension test scores.

Table 2. ANCOVA result of the explicit and implicit comprehension

Dimension	Group	Mean	S.D.	Adjusted Mean	F	η^2
Explicit comprehension	AR storybook	3.40	0.498	3.39	$F = 0.134$, $p > 0.05$	0.002
	Paper storybook	3.43	0.504	3.44		
Implicit comprehension	AR storybook	6.37	0.850	6.31	$F = 56.99$, $p < 0.05$	0.50
	Paper storybook	4.73	0.907	4.79		

3.2 Results of the story retelling test

Table 3. ANCOVA result of the story retelling

Group	N	Mean	S.D.	Adjusted Mean	F	η^2
AR storybook	30	27.17	1.967	27.77	$F = 189.54$, $p < 0.001$	0.77
Paper storybook	30	23.23	2.269	22.12		

Having determined that the homogeneity of the regression slopes ($F = 0.504$, $p > 0.05$) and Levene's test for homogeneity of variance ($F = 0.251$, $p > 0.05$) met the assumptions for the use of ANCOVA, an ANCOVA was used to examine the story retelling scores of the two groups. As shown in Table 3, there was a significant difference

between the two groups of students on story retelling ($F = 189.54, p < 0.001$), with students in the AR storybook group performing higher (adjusted mean = 27.77) than those in the paper storybook group (adjusted mean = 22.12). The results ($\eta^2 = 0.77$) showed that AR storybooks had a very large effect on students' story-retelling performance. This effect size indicates that a substantial portion of the variance in story retelling can be attributed to the use of AR storybooks.

3.3 Results of the reading motivation test

After confirming the homogeneity of the regression slopes ($F = 3.586, p > 0.05$) and Levene's test for homogeneity of variance ($F = 0.092, p > 0.05$), this study used ANCOVA analysis to analyse the reading motivation of both groups. The results of ANCOVA found a significant difference in reading motivation between the two groups ($F = 53.02, p < 0.001$), with students who used AR storybooks showing higher motivation to read (adjusted mean = 46.90) than those who used paper storybooks (adjusted mean = 39.57). The results ($\eta^2 = 0.48$) showed that AR storybooks had a large effect on students' reading motivation performance.

Table 4. ANCOVA result of the reading motivation

Group	N	Mean	S.D.	Adjusted Mean	F	η^2
AR storybook	30	47.07	4.234	46.90	$F = 53.02,$ $p < 0.001$	0.48
Paper storybook	30	39.40	4.264	39.57		

4 DISCUSSION

The main purpose of this study was to investigate the effects of reading AR storybooks and paper storybooks on the reading comprehension of primary school students. The study results showed that using AR storybooks with AR effects significantly improved students' reading comprehension, story retelling, and reading motivation. AR technology provides students with an immersive and interactive reading experience that improves reading efficacy in primary school students.

Interacting with AR storybooks provides a multi-sensory reading experience, such as the senses of sight, hearing, and touch. According to Piaget's stages of cognitive development, elementary school students and early adolescents are in the concrete operational stage, where they need to see, hear, or use other senses to understand [22]. Therefore, the strong visualisation features of AR play a crucial role in students' learning at this stage. Additionally, the CTML posits that students learn more effectively when presented with both visual and auditory information, as it reduces cognitive overload and enhances understanding. This theory supports the findings of this study, as AR storybooks combine visual and auditory elements, making the learning experience more engaging and effective.

4.1 Research question 1

This study found that using AR storybooks significantly improved students' reading comprehension scores, particularly in the area of implicit comprehension.

However, the two groups of students had no significant difference in explicit comprehension. A plausible explanation is that AR storybooks provide an immersive reading experience where students can interact with the story's characters, allowing them to pay more attention to story details. In addition, multimedia features such as animation and sound in AR storybooks help students understand the content, thereby improving their implicit comprehension. Regarding explicit comprehension, the lack of significant difference between AR and paper storybooks can be primarily attributed to the fact that explicit understanding largely depends on students' fundamental reading skills and direct acquisition of textual and pictorial information. As these two aspects remain essentially consistent across both AR and paper storybooks, the effectiveness of AR and paper storybooks in this domain does not exhibit substantial variation.

This finding is consistent with Liu et al.'s [31] study, which found that AR storybooks significantly improved second-grade students' reading comprehension of traditional Chinese storybooks, especially in implicit comprehension. Similarly, Şimşek and Direkçi's [18] study found that the AR storybook group had much higher overall comprehension scores than the traditional book group. They also found that, while there was no difference in literal comprehension between the two groups, there was a significant difference in inferential comprehension. Danaei et al. [32] conducted a quasi-experimental study that further investigated the effects of reading AR storybooks versus paper books on students' reading comprehension and supported these findings. The results of this study also proved that the advantages of using paper books for reading, as suggested by previous studies, were not found in this study [35].

The results highlight the potential of AR storybooks to enhance implicit reading comprehension, suggesting that AR could be particularly effective in fostering deeper, inferential reading skills. For educators, AR storybooks could serve as a useful tool to help students engage more with complex texts that require an understanding of implied meanings. However, explicit comprehension, which involves more direct retrieval of information, might benefit more from traditional reading strategies, indicating that a balanced approach combining both AR and traditional reading methods could be the most effective in comprehensive literacy instruction.

4.2 Research question 2

This study found that reading with AR storybooks improved students' story retelling more than reading with paper storybooks. The various effects provided by AR storybooks, such as animation, music, and character movements and expressions, help students better understand the character's emotions and the development of the storyline. This enables them to memorise the story details better, understand the storyline more deeply, and consistently remember the story. These findings are consistent with Çetin and Ulusoy's [36] study, which found that augmented reality-based reading environments improved oral retelling skills in third-grade students. Similarly, the results of this study are consistent with those of Liu et al. [31], who found that students who used AR storybooks significantly improved their story-retelling performance, particularly in terms of story context and storyline.

Nevertheless, the animations, sounds and interactive elements in AR applications may distract students, causing them to focus more on visual and interactive effects rather than the story itself. Tobar-Muñoz et al. [30] found that incorporating

game elements into AR reading environments might diminish students' attention to the story content, affecting their retelling performance. Overly strong interactivity or poorly designed AR content can interfere with the understanding of core story elements. Antoniadis [37] reported that no statistically significant difference was observed between the experimental group using AR and the control group following traditional methods in teaching children about plants. In the study conducted by Danaei et al. [32], AR-enhanced storybooks demonstrated notable advantages in overall reading comprehension, with particular strengths in addressing implicit questions. However, when it came to story retelling, such as themes and settings, the performance was comparable to traditional formats, showing no significant difference. Despite AR appearing to help with remembering more episodes and providing a sequential retelling. Both groups struggled to identify the characters and the main problem.

The findings suggest that AR storybooks can be particularly useful for improving students' story-retelling skills, which are closely linked to their narrative comprehension and oral expression abilities. This has important implications for educational practice, as retelling is a critical component of language development and narrative skills. Teachers can integrate AR storybooks into their curricula to enhance students' ability to recall and articulate story details. However, care must be taken to ensure that the interactive elements do not overshadow the narrative, which would detract from the intended learning outcomes.

4.3 Research question 3

The study's results suggest that using AR storybooks can increase students' reading motivation. The different features of AR make students more interested and engaged in the story and improve their comprehension, which increases their motivation to read. By interacting with the characters in the AR storybook, students can focus more on the story, helping them to pay attention to details and retain more content. The ability to feel and understand the story through AR storybooks increases students' self-confidence and reduces their cognitive load, improving their reading motivation and satisfaction with AR storybooks. Interacting with AR storybooks provides a multi-sensory reading experience, such as the senses of sight, hearing and touch. According to Piaget's stages of cognitive development, elementary school students and early adolescents are in the concrete operational stage, where they need to see, hear, or use other senses to understand [22]. Therefore, the strong visualisation features of AR play a crucial role in students' learning at this stage.

This study's results are consistent with Roumba and Nicolaidou's findings [38], who observed that AR books can increase adolescent students' motivation to read, with children maintaining positive attitudes and behaviours towards AR. Similarly, Cheng [39] found that students who read AR books experienced lower cognitive load, higher motivation, and more positive attitudes. Redondo et al. [40] found that incorporating AR into early childhood English education increased students' motivation and helped to build more positive socio-affective relationships among young children. In addition, previous studies in different subject areas have shown that AR increases learner motivation. For example, Erbas et al. [41] used AR in a biology classroom and found that students in the experimental group showed higher motivation. Liu et al. [42] found that integrating AR into EFL students' learning enhanced their intercultural competence and increased their L2 motivation.

5 CONCLUSIONS

The rapid advancement of technology has transformed the reading environment for students. As an emerging technology, AR has been shown to support students' learning. This study shows that reading with AR storybooks can significantly improve students' reading comprehension, particularly implicit comprehension, story retelling and reading motivation. However, these findings do not suggest that AR storybooks should completely replace paper storybooks; both should be combined.

Like other studies, this one also has limitations that future research must consider. First, as the books used in this study were storybooks, the results cannot be generalised to other disciplines, such as nature books. Future research could explore the use of AR in science, technology, engineering, and mathematics (STEM) to determine its role in these subject areas. Secondly, the number of participants in this study was not large enough, and future studies could use a larger sample to obtain more robust results. Moreover, the convenience sampling method employed in this study may lead to limited sample representativeness, potentially restricting the generalisability of our findings. This sampling approach could introduce self-selection bias, resulting in sample characteristics that differ from the broader population. Future research should consider more rigorous sampling methods, such as stratified random sampling, and conduct replication studies in diverse contexts to validate and extend the current findings.

Additionally, technological limitations were encountered, such as device availability and student familiarity with AR technology, which were addressed through organised rotation schedules and preliminary training sessions. Finally, this study only compared the effects of AR storybooks and paper storybooks on students' reading without including instructional strategies. Besides, this study's findings contrast with previous research, such as Tobar-Muñoz et al. [30], which suggests that including gaming elements in AR could influence outcomes. Future research could consider incorporating strategies and more AR elements such as gamification, self-regulation, problem- and project-based learning into AR storybooks [43], [44], [45]. In addition, future studies should also consider using mixed methods to evaluate AR interventions comprehensively [46].

This study also has its theoretical and practical significance. This study contributes to the theoretical understanding of how AR technology affects educational outcomes. By examining the effects of AR storybooks on reading comprehension, story retelling, and reading motivation, this study provides empirical evidence to support the incorporation of AR into educational theory. The findings suggest that AR can increase cognitive engagement and motivation, which is consistent with the CTML and reduces cognitive load. This study also extends the application of Piaget's stages of cognitive development (particularly the concrete operations stage) by demonstrating how the powerful visualisation capabilities of AR can facilitate learning for primary school children and adolescents.

This study has practical implications for educators and curriculum designers. The positive impact of AR storybooks on reading comprehension and motivation highlights the potential of AR as a pedagogical tool in the classroom. Educators can improve student engagement and learning by incorporating AR into reading programs. Moreover, AR storybooks can be effectively integrated into diverse educational settings, including urban and rural schools, various grade levels, and different subject areas. Additionally, AR can be applied across various subjects beyond reading, such as science and history, to help students visualise complex concepts and make learning more tangible. In addition, the study suggests that AR and traditional

paper storybooks should be used together to provide a balanced approach to reading instruction, combining the benefits of both digital and print media to cater to diverse learning needs and preferences.

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