Augmented Reality Books: Motivation, Attitudes, and Behaviors of Young Readers

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Abstract—Augmented Reality (AR) books show potential to increase young learners' reading motivation, which is important given children's declining reading motivation over the school years. Previous studies measured reading motivation only in higher education and only after users' experience with AR. Few empirical studies focused on primary education children and those examined attitudes, not motivation. This study aimed to: a) examine how young children's motivation changes through the experience of reading AR books and b) document their attitudes and behaviors after this experience. The theoretical framework was based on Keller's ARCS model of motivation. Participants in this pre-test post-test case study were 40 fourth and fifth graders. Data sources included validated questionnaires and an observation protocol of children's behavior while interacting with AR books. Children's motivation had a statistically significant increase in attention ($t_{39} = –3.07$, $p < 0.01$), confidence ($t_{39} = –2.44$, $p < 0.05$) and satisfaction ($t_{39} = –3.26$, $p < 0.01$). Children showed a high level of enthusiasm with AR technology when interacting with the first AR book, which notably decreased with the second book. The children maintained positive attitudes and behaviors towards AR. The study showed that even through short-term interactions, AR books have the potential to increase young students' reading motivation. It adds to our knowledge concerning the use of AR books by primary school children, who are under-represented in the literature. Directions for future research are drawn.

Keywords—augmented reality, reading motivation, attitudes, behaviors, primary school, young children

1 Introduction

Advances in technology provide the opportunity to better support learners' cognitive needs and to create student-centered learning environments [1] that enhance students' motivation to learn. Examples of innovative student-centered learning environments include web-based interactive learning environments [2], [3], gamified applications for mobile devices [4], applications employing the Internet of Things [5], immersive virtual reality applications, and augmented reality (AR) applications. These emerging technologies allow for immersive and experiential learning within a classroom [6] while at the same time being motivational for learners to use.

Technological advances have affected students' reading. Technology-enabled reading has become increasingly popular. AR applications with educational features offer young readers an exciting experience [7], and augmented reality is expected to increase students' learning attitudes [8]. Digital technologies enable modern reading to be more convenient and are expected to increase children's reading interest [4], [9] and enhance early childhood literacy [10]. However, parental concerns associate digital books with leading children to lose interest in print books [11]. Augmented reality books combine physical books with the interactive potential provided by digital media, such as 3D graphics accessible using a QR Code and a mobile device. They constitute a playful and engaging way for enhancing teaching and learning [1] that at the same time addresses parental concerns. Augmented reality books have been recently shown to improve reading comprehension compared to print books in a small scale study with 34 children aged 7 to 9 [12] and in a study with 89 secondary school students [13].

Data suggests a reduction in the number of readers worldwide and a decreasing amount of time spent on reading [14]. For example, the percentage of middle school students who read on a daily basis declined significantly during the last decades [15]. Studies show that even though kindergarten children have high motivation for reading [16], many children's motivation to read declines over the school years [17]. Lee and Zantall (2017) also found that motivation and reading behavior decrease from elementary to middle school [18]. Similarly, the relation of students' attitudes and beliefs about reading with actual reading is weaker for middle school students compared to elementary school students, as shown by meta-analyses, which is another indication of declining motivation for reading over the school years [19]. Therefore, it is crucial to examine whether augmented reality books' affordances increase young children's motivation for reading. The present study focuses on a) examining how young children's motivation for learning changes and b) documenting their attitudes and behaviors after reading two AR books. What is unique in this study is that it focuses on young children, a target population underrepresented in this field. Moreover, the study implements a pre-post experimental methodology to measure the effect of AR on children's motivation, which was not encountered in any other study in the field at this age group.

1.1 Related work

Earlier contributions explored the problem of low or declining motivation for reading by suggesting intervention programs that did not necessarily use technology [20], [21] and interventions that involved e-reading on screens [22] and AR textbooks [23] that indicated that technologically supported interventions have the potential to increase students' reading motivation. Previous studies focused on the impact of AR tools in different levels of formal education and different application domains. Studies focused on the effect of AR tools on university students' foreign language learning and vocabulary [24], [25], on middle school students' performance in biology [26] and science [27], on primary school students' storytelling skills [28] and on kindergarten students' art education [29]. Only a small percentage (16%) of reviewed studies in the field of AR applications were conducted in primary education, based on a meta-analysis of papers published between 2001–2019 [30]. With respect to AR books, in particular, several

research studies focused on the use of AR books by university students [31]–[35] to examine their cognitive load, motivation, and attitudes [33], [34] to examine their learning in Biology [35], and to examine their motivation and improvement in academic performance [31], [32]. The majority of previous studies measured attitudes and behaviors, such as acceptance, adoption, and confidence towards AR books targeting adults, for example, university students [33] or future teachers [6], [36] or parents [37]–[39]. The studies that targeted parents examined their interaction with young children while reading AR books [37], [39]. The most commonly used methods for data collection in studies that used augmented reality in educational settings were questionnaires [40].

Fewer research studies focused on the use of AR books by young children, and those primarily focused on their interaction with and attitudes towards AR books [1], [41]–[44] and did not address their reading motivation. Related work involving primary school students investigated how young children interact with augmented reality storybooks using observational methods [34], [35]. Dunser and Hornecker (2007) had a deliberate sample of good readers in their study and were interested in studying how interactivity supports collaborative learning. Their methodology included individual interviews post-experience [41]. Dunser and Hornecker (2007) showed that AR books that allow children to engage with the content interactively might be a suitable learning medium to support low-ability readers [42]. Following up on this direction, Meletiou-Mavrotheris et al. (2020) exploited the affordances of AR to address the underachievement of European youth in reading skills [1]. Their study focused on teachers and upper primary and lower secondary school students. Results from 100 students, the vast majority of whom were aged 11–12, showed relatively positive attitudes towards reading in general and through using AR. Working with younger children, Yilmaz et al. (2017) examined preschool students' attitudes towards augmented reality picture books [43].

Lastly, a study that explored the potential of AR books to influence the reading attitudes of 8–9-year-old children showed that the majority of young children who had positive attitudes towards reading before their first experience with an AR book enjoyed reading an AR book. Quantitative data analysis showed the majority of children claiming that they would read books with a higher frequency if those were AR books [45]. However, qualitative data analysis revealed contradictory findings, as a significant number of children that cannot be dismissed (40%, 12/30) seemed to find "reading enhanced with the AR experience" unattractive [45], signaling the need for further studies on young children's attitudes and motivation to use AR books.

1.2 Necessity of study

Previous studies that measured reading motivation in relation to AR books were only conducted in higher education and measured motivation only after users' experience with AR [25], [32], [34]. The only study identified in the literature that measured motivation pre and post an AR experience with children was a recent study by [46], which focused on lower primary school children's geometry performance and not reading. Even though measuring motivation or attitudes once, appears to be common practice [45], [47], there are limitations in this approach as it misses a baseline measurement and therefore cannot detect changes in students' motivation nor compare students' motivation before and after an AR experience.

The present study focuses on young children, a target population underrepresented with respect to research in AR books. It furthermore uses a pre-post experimental methodology, which allows establishing a baseline and comparing children's motivation before and after the AR experience, an element that is missing from previous studies. As a second aim, in line with previous studies that investigated participants' reading habits and attitudes in upper primary and lower secondary school [1] or pre-school [43] relying on post-surveys administered to students at the end of the program or intervention, the present study documents primary school children's attitudes and behaviors after an AR experience.

2 Methodology

This study examines changes in children's motivation for learning after reading Augmented Reality books and documents their attitudes and behaviors after the AR experience.

2.1 Research design

The research design of the study was a pre-test post-test case study.

2.2 Research questions

a) How does the motivation of 4th and 5th-grade students change after reading Augmented Reality books?
b) What are 4th and 5th-grade students' attitudes and behaviors after reading Augmented Reality books?

2.3 Participants, sampling, and ethical concerns

The study was conducted according to the World Medical Association Declaration of Helsinki. The study followed American Psychological Association (APA) ethical standards and General Data Protection Regulation (EU) 2016/679 (GDPR) guidelines. Its protocol is in accordance with the guidelines provided by the University Ethics Committee, and it was approved by the country's National Bioethics Committee (ΕΕΒΚ ΕΠ 2019.01.158, Sep13th 2019) and by the country's National Center for Educational Research and Evaluation (7.15.06.15. 1/3, October 25th, 2019). After receiving approval for conducting the study by the Director of Primary Education and by the principals of two public primary schools located in the second major city of the country (convenience sampling), all 4th and 5th-grade students' parents received a letter explaining the aim of the study and inviting their children to participate in the study. The requirements of the study included children's participation in two individual 2-hour meetings with the researcher scheduled in non-school time over approximately two weeks. The total number of children who received an invitation letter was 180.

A total of 40 students (22%, 40/180) responded positively and accepted the invitation by having their parent or guardian sign an informed consent form to participate in the study voluntarily. Therefore, participants of the study included 20 4th grade students (12 boys; 8 girls) and 20 5th grade students (11 boys; 9 girls).

2.4 Data sources

Three data sources were used for this study: a) a questionnaire measuring motivation, b) a questionnaire measuring attitudes and behaviors, and c) an observation protocol of children's behavior while engaging with AR books, which was combined with timing children's behavior.

The first data source was a reliable questionnaire to measure three dimensions of motivation: attention, confidence, and satisfaction [34], based on Keller's ARCS model of motivation [48]. It consisted of 10 items, accompanied by a 5-point Likert scale ranging from Completely disagree to Completely agree. Example statements are the following: "I pay attention to read the AR book continuously" (attention) [34], "I believe that reading with the aid of AR technology can be helpful for better understanding the content of the book" (confidence) [34], and "I am dissatisfied with the experiences of the AR book reading" (satisfaction) [34]. The last statement, which was negatively phrased, was scored reversely. The motivation instrument had an overall reliability alpha value of 0.88. Cronbach's alpha for each dimension measured was as follows: Attention scale = 0.82 (four items), Confidence scale = 0.80, (three items), and Satisfaction scale = 0.76 (three items) [34]. The motivation questionnaire was administered pre- and post.

The second data source was a questionnaire measuring attitudes (perceived control and perceived usefulness) and behaviors (behavior of learning and behavior of AR learning) [34]. The questionnaire consisted of four items for perceived control, four items for perceived usefulness, five items for learning behavior, and four items for the behavior of AR learning. A five-point Likert scale was used, ranging from 1 (Completely disagree) to 5 (Completely agree). Example statements are the following: "I think the AR book is easy to use" (Perceived control) [34], "The AR book can help me understand the content more clearly" (Perceived usefulness) [34], "I hope to read more information regarding the topic of the AR book" (Behaviour of learning) [34] and "I hope to have more opportunities to learn using AR technology" (Behaviour of AR learning) [34]. "The overall reliability alpha value was 0.87. The overall reliability alpha values were 0.75, 0.77, 0.89, and 0.82 for each scale, respectively, indicating satisfactory internal consistency of the survey" [34].

The third data source was an observation protocol of children's behavior while engaging with AR books, which was combined with timing their behavior. Behaviors that were recorded for each child were the following: a) reads fluently or has difficulty reading, b) appears concentrated or appears bored, c) reluctantly turns pages or appears motivated to read the next page, d) interrupts the reading process to ask a question that is relevant/irrelevant to the content or does not interrupt the process, and e) appears excited with AR.

2.5 Data collection

Each child had two individual meetings with the first author of the study. During the first meeting, participating children were asked to complete the motivation questionnaire as a pre-test. They were then asked to read an AR book whose theme focused on some of the most important world's monuments. Children read a second AR space-themed book focusing on the Sun and other planets in the second meeting and then answered the same motivation questionnaire as a post-test. They also completed an attitudes and behaviors questionnaire. Children used a smartphone on which the AR application accompanying the book was pre-installed. They accessed 3D models of monuments in the first book and 3D models of planets in the second book, which included sound, using QR codes printed in these books. During both meetings, the first author timed children's active reading. Active reading time is operationalized as the time children spent reading the book, excluding any visible interruptions of their reading. If children interrupted their reading for any reason, such as asking a question, the timer was paused during that time. The first author also completed an observation protocol for each child. The first author acted as a passive observer in the study without participating or affecting the process in any way. She only answered children's clarifying questions, if there were any, concerning the statements included in the instruments. She did not participate in the process of reading the book, which was an activity that children engaged in individually at their own pace. The duration of each meeting was approximately 1.5 hours. The time in-between the two meetings varied from one to two weeks.

2.6 Data analysis

All quantitative data were input into a statistical package (IBM SPSS Statistics 25). For the analysis of RQ1, each dimension of motivation (attention, confidence, and satisfaction) was calculated as the composite score consisting of children's answers in the three or four relevant Likert-scale items. Students' answers in negatively phrased statements were reversed before calculating the composite score. Pre-test and post-test motivation scores were compared using paired samples t-tests. An alpha level of 0.05 was set a priori for these statistical analyses.

The same procedure was followed for the dimensions of the questionnaire measuring attitudes (perceived control and perceived usefulness) and behaviors (behavior of learning and behavior of AR learning). Descriptive statistics (M, SD) were used for the study's second research question to report children's attitudes toward AR books.

3 Results

3.1 RQ1 changes in motivation after reading augmented reality books

The first research question attempted to examine changes in children's motivation after reading two AR books. Table 1 shows children's motivation in three dimensions (attention, confidence, satisfaction) before and after reading AR books.

Table 1. Children's motivation in three dimensions (attention, confidence, satisfaction) before and after reading AR books

	Pre-test		Post-test	
	M	**SD**	**M**	**SD**
Attention	3.91	0.68	4.17**	0.56
Confidence	4.06	0.86	4.35*	0.58
Satisfaction	3.74	1.13	4.16**	0.77

Notes: * indicates $p<0.05$; ** indicates $p<0.01$.

Children's motivation to learn had a statistically significant increase in all three dimensions of attention, confidence and satisfaction. Specifically, their attention increased from M = 3.91 (SD = 0.68) to M = 4.17 (SD = 0.56) [$t_{39} = –3.07$, $p = 0.004$]. Similarly, their confidence increased from M = 4.06 (SD = 0.86) to M = 4.35 (SD = 0.58) [$t_{39} = –2.44$, $p = 0.019$], and, the most note-worthy change was found for satisfaction, which increased from M = 3.74 (SD = 1.13) to M = 4.16 (SD = 0.77) [$t_{39} = –3.26$, $p = 0.002$], respectively.

Children spent on average 48 minutes actively reading the first book (M = 48.26, SD = 10.53, min = 29, max = 80) during their first meeting and 46 minutes reading the second book (M = 46.25, SD = 9.34, min = 29, max = 75) during their second meeting with the researcher. Using the Spearman's rho coefficient, correlation analysis was conducted between the time students spent reading AR books and their responses to specific questions revolving around their attention, happiness, and satisfaction while reading such books. A statistically significant moderate positive correlation (Spearman's rho = 0.33, p = 0.033, N = 40) was found between the total time children spent actively reading AR books (M = 94.52 minutes, SD = 18.80) and their response concerning continuous attention while reading AR books (M = 4.13, SD = 0.72). A statistically significant moderate positive correlation (Spearman's rho = 0.4, p = 0.010, N = 40) was also found between the total time children spent actively reading AR books (M = 94.52 minutes, SD = 18.80) and their reported happiness while reading AR books (M = 4.23, SD = 0.77).

Finally, a statistically significant moderate positive correlation (Spearman's rho = 0.35, p = 0.027, N = 40) was found between the total time children spent actively reading AR books (M = 94.52 minutes, SD = 18.80) and their reported overall satisfaction after reading AR books (M = 4.17, SD = 0.77). These findings indicate that the more time children spent actively reading AR books, the greater their reported attention, happiness, and satisfaction from reading AR books.

3.2 RQ2 children's attitudes and behaviors after reading augmented reality books

The second research question focused on measuring children's attitudes and behaviors after the AR book reading experience. As Table 2 shows, children's attitudes towards the AR books were positive, as their perceived control (M = 4.13, SD = 0.66) and perceived usefulness (M = 4.15, SD = 0.54) mean scores exceeded 4 out of 5. This finding indicates strong agreement with statements regarding children's ability to control the technology and use it unassisted without difficulty (perceived control) and strong agreement with statements regarding the usefulness of AR books for children's

understanding of the topic of the books (perceived usefulness). The children had positive behavior towards AR books, as the same finding was observed for the behavior of learning (M = 4.03, SD = 0.68) and behavior of AR learning (M = 4.22, SD = 0.71), both of which were evaluated positively.

Table 2. Children's attitudes and behavior after reading AR books

Attitudes and Behaviors	Dimensions	Post AR Experience	
		M	SD
Attitudes	Perceived control	4.13	0.66
	Perceived usefulness	4.15	0.54
Behaviors	Behavior of learning	4.03	0.68
	Behavior of AR learning	4.22	0.71

Children generally thought that AR technology was easy to use (37/40, 93.5%) and that they could learn how to use it in a short time (33/40, 83%). They agreed or strongly agreed that AR books are helpful for learning (36/40, 34/40, 87.5%) and can help them better understand the content (37/40, 36/40, 91%). AR helped children think of different ideas (35/40, 33/40, 85%); thus, they considered AR an alternative learning method (33/40, 34/40, 84%). After reading AR books, children wanted to learn and read more information about the topics of the books, specifically about the world's monuments (33/40, 83%) and about space (32/40, 80%). They hoped to have an opportunity to learn more about AR technology (33/40, 83%), to read additional AR books on different topics (36/40, 90%), and expected more AR applications in learning (33/40, 83%).

Based on the results of the observation protocol, during children's reading in the first and second meeting, almost all children read comfortably (37/40, 92.5%), they seemed focused while reading the book (35/40, 87.5%), and they were eager to turn the pages and read more (35/40, 87.5%). They asked questions and some children made comments that were relevant to the topic of either the first book (19/40, 47.5%) or the second book (16/40, 40%).

The enthusiasm with AR was measured by recording the frequency of children's gestures, facial expressions, and exclamations. Examples of behaviors that indicated enthusiasm with AR included: e.g., the child raising their eyebrows showing surprise, the child saying "wow", the child saying "wow, cool, I've never seen anything like this", etc. The maximum number of behaviors showing enthusiasm reported for a single child was 5. There was more enthusiasm with AR in the first book, as 44 instances of enthusiasm were recorded compared to 18 instances of enthusiasm recorded in the second book. One indication of enthusiasm was recorded for 11 children, two indications of enthusiasm for 12 children, and two indications of enthusiasm for three children. Four and five indications of enthusiasm were recorded for only one child.

4 Discussion

Earlier studies explored the problem of children's low or declining motivation for reading by suggesting intervention programs at different grade levels [20]–[22]. The use of AR applications in an educational environment for enhancing motivation is

a relatively recent development [23]. Further studies are needed to ensure they are utilized in the most effective way [13]. This study aimed to examine how young children's reading motivation changes through the experience of reading Augmented Reality books and to document their attitudes and behaviors after the experience of reading two AR books.

With respect to the study's first aim, children's motivation significantly increased in all three dimensions of attention, confidence and satisfaction. The highest change from pre-test to post-test was found for satisfaction. This finding is corroborated with the results of a previous quasi-experimental study that used AR books in science in formal education and also found their positive impact on students' satisfaction [23]. The results of the first research question of our study showed that even a short-term use of augmented reality books increases young children's motivation for reading. This is a significant finding in light of studies showing that even though kindergarten children have high motivation for reading [16], many children's motivation to read declines over the school years [17]. Previous studies [25], [32], [39] assessed motivation only once, missed a baseline measurement, and could not detect changes in students' motivation nor compare students' motivation before and after an AR experience. Our study overcame this limitation and showed that AR books, as emerging technologies, have the potential to positively affect young students' motivation to read and potentially contribute to an increase in children's reading interest [4]. This finding is in accordance with the existing research literature showing the positive impact of the augmented reading approach on students' motivation [32], [34], [37], [43] and reading interest [9]. More specifically, the study's findings with young children agree with the results of Cheng (2017), who used the same instruments for measuring motivation and attitudes of higher education students, and found that, in general, university students had stronger motivation and more positive attitudes towards their learning experiences when reading an AR book [34]. Children's increased motivation for reading over time is a significant finding in relation to the positive correlation found in this study between the time children spent actively reading books and their self-reported attention, happiness, and satisfaction from reading AR books. The findings of this study indicate that the more time children spent actively reading AR books, the higher their reported motivation. This corroborates findings from the literature that reported positive relationships between motivation and reading activity [49].

The study's second research question documented positive attitudes towards reading in general and towards reading using AR in particular. Findings agree with previous studies that showed relatively positive attitudes with children who were older than the participants in our study, e.g., lower secondary school students [1] and higher education students [34], as well as younger than the participants in our study, e.g., pre-school students [43]. Therefore, the study adds to our knowledge concerning the use of AR books by primary school children, which was missing from the literature in which young children are under-represented.

Our study showed a high level of enthusiasm with AR technology when children interacted with the first AR book, which notably decreased when children interacted with the second AR book. This potentially indicates a novelty effect, also reported in studies with pre-primary and secondary school children [13], [44]. Bursali and Yilmaz (2019) suggested that "to mitigate this effect, it may be beneficial for the students to be

allowed to interact with this technology for a period of time before the start of the actual application or intervention" [13].

In conclusion, after reading AR books, children's motivation for learning increased. They seemed to have positive attitudes towards AR in general and the learning behavior with AR in particular.

4.1 Limitations

A weakness of the study is the limited generalizability of its findings due to the self-selected nature and relatively small size of the sample of children who interacted with AR books. The study was based solely on quantitative data. Qualitative data in the form of individual, semi-structured interviews with children and their parents or teachers would help triangulate the study's findings. The study's short duration was another limitation.

4.2 Instructional implications

AR books combine traditional books with digital tools that are easy for young children to access even without the help of an adult (teacher or parent). Educators who lack the technological background or training to integrate advanced technological tools in the curriculum [50] may prefer to use AR books as supporting tools for children in typical primary school classrooms. Children can use AR books in their native language or as part of learning a second language, individually or in small groups. AR books can be used in a typical classroom setting, without the need of additional equipment other than a device that can read a QR code, such as a tablet or a mobile phone, which children can bring to school as part of a Bring Your Own Device (BYOD) initiative. Therefore, mainstream adoption of already-developed AR books might be feasible in formal primary education reasonably soon, especially considering the proliferation of mobile touchscreen technologies to which children have access [51].

The study contributes valuable insights into the growing body of AR-enhanced learning and AR-enhanced reading. In line with relevant literature, our study highlighted some of the potential benefits of using AR for educational purposes and informal learning, which can be helpful for the development of educational AR products targeting young children [7].

4.3 Future research directions

When children are meant to experience a book's story on their own, which is a typical scenario in upper primary school, it is important to verify that concepts are appropriate for the targeted age level of children and that children can understand these concepts [41]. This study did not examine children's level of understanding of the story. Future research can focus on examining students' understanding and learning performance through AR books, especially in light of studies indicating that AR books and app books increased children's interest in storybooks but decreased their reading concentration [9]. Other directions for future research may focus on technology-facilitated

collaboration among children while reading AR books and on providing AR books that adapt to different learning styles [52].

The results of the study by Agorou et al. (2018) indicated the need for further research with struggling readers [45]. The majority of the present study's participants (37/40, 92.5%) were fluent readers. Recent studies [1], [53]–[55] have shown that AR activities can be beneficial for different types of learners, including students who may experience reading difficulties. Learning gains were reported both with respect to reading comprehension as well as with respect to motivation for reading [1], [53]–[55]. Longitudinal, quasi-experimental studies including a control group focusing on struggling readers are needed to advance our understanding of how AR technology can best benefit different types of learners with respect to their motivation for reading, reading comprehension, concentration, and collaboration skills.

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