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The Impact of Multi-Sensory AR Learning on Student' Historical Understanding: An Example of the Riverside Scroll at Qingming Festival

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ABSTRACT

This study aimed to develop and evaluate an augmented reality (AR)--based museum literature book to enhance seventh-grade students' interest in and understanding of history learning in the Palace Museum in Beijing, China. Traditional history museums are deficient in developing and utilising AR technology to engage and stimulate young audiences' interest in history learning. The research methodology included an experiment conducted with 31 seventh-grade middle school students who used multi-sensory experiences with AR books involving visual, auditory, tactile, and kinesthetic experiences. The results showed that using AR books significantly increased students' interest in learning, their interactive behaviour, and their retention and comprehension of historical knowledge. The conclusions suggest that AR books, as an innovative educational tool, enhance students' historical understanding and critical thinking skills and stimulate their interest and emotional response to history learning. Future research should further explore the application of AR technology in different educational settings to provide more practical and theoretical support.

Keywords: Augmented Reality, Cultural Heritage, Historical Museums, Museum Education, Multi-sensory Learning

INTRODUCTION

In recent years, research on technology integration in educational environments has received a lot of attention with the emergence of Augmented Reality (AR) technology. AR can create immersive and interactive experiences that enhance learning. Museums act as informal learning environments, providing historical education through exhibitions and educational programmes that help young people understand historical facts and develop critical thinking (Hooper-Greenhill, 2007). AR technology can make museum exhibitions more engaging and educational, especially for younger audiences. Research has shown that AR promotes understanding and memory through interactive and visually stimulating content. However, many museums in China still rely on traditional static exhibitions, making it difficult to meet the interactive learning needs of young people (Parker & Saker, 2020). Although AR technology demonstrates great potential, its application in museum education is still in its early stages. This study aims to develop an AR-based educational book to enhance young people's interest and understanding of history and cultural heritage. Research on AR in education is progressing, with many studies demonstrating its effectiveness. Some museums have used AR to facilitate exhibition viewing and enable children to experience content more interactively (Chang et al., 2023). However, AR content in traditional museums is poorly developed and usually involves only simple features that are not effective in enhancing children's interest and learning (Parker & Saker, 2020). In this study, an AR learning book was developed to demonstrate the historical background, cultural values, artistic features, and significance of Song Dynasty society using the Riverside Scroll at the Qingming Festival. The goal is to provide a tool that supports museum education and enhances young people's learning interests and emotional engagement. Previous research has highlighted the limitations of museum exhibitions in engaging young people and the importance of interactive and multi-sensory experiences (Vanderschantz et al., 2018). Furthermore, research has shown that AR can reverse the trend of declining interest in cultural heritage among adolescents (Ntagiantas et al., 2021).

This study explores the use of AR technology in museum books and its impact on young people's history learning, based on multisensory learning theory (Fleming & Mills, 1992), and asks the following questions:

a. RQ1: How do multisensory experiences affect young people's interest and emotional responses in museum learning?
b. RQ2: How do multisensory books using AR technology affect student academic performance?

LITERATURE REVIEW

Status and Challenges of Museum Education

According to the International Council of Museums (ICOM), museums are institutions open to the public that acquire, preserve, research, disseminate, and present the tangible and intangible heritage of humanity and its environment for public education, learning, and enjoyment (ICOM, 2007). Museum education, as a form of informal education, aims to promote learners' understanding of science, art, and

culture through exhibits and interactive activities. However, traditional museum education often relies on display boards and guidebooks that lack interactivity and appeal. Research has shown that such static displays are challenging to stimulate deeper thinking and long-lasting memories among visitors. Particularly for young audiences, it is difficult to maintain interest and attention for extended periods (Parker & Saker, 2020). In recent years, museums have faced declining interest from younger generations and a decrease in the number of visitors (Knutson & Crowley, 2022). To increase visitor interest and engagement, it has become important to design engaging learning experiences. Traditional museum education, however, has significant shortcomings in providing interactive and immersive experiences and is often limited by space and time to offer a comprehensive and flexible learning experience (Steinicke, 2016).

Application of AR Technology in Education

With the development of AR technology, its application in education has attracted significant attention. AR technology is believed to improve the educational effectiveness of traditional museum exhibitions by increasing interactivity and immersion (Roussou, 2001). Research has shown that using AR in education can significantly enhance student learning and motivation. For example, experiments conducted at the Arizona Science Center and the Arizona Museum of Natural History found that a gamified quiz model created through AR significantly increased learner engagement and the number of questions asked (Nelson et al., 2020). Additionally, designed AR games significantly enhanced learners' emotional connections and meaningful experiences (Khan et al., 2020). In museum education, AR technology can support educational activities by providing rich and realistic 3D images that activate the senses. For instance, in the UNESCO World Geopark Psiloritis, virtual reconstructions of historical heritage and interactive guided tours allowed users to directly manipulate activities, ultimately increasing audience interest and learning through meaningful immersion (Caridakis, 2021; Roussou, 2001). The effectiveness of AR for education has also been demonstrated in art museums, where augmenting the 3D display of exhibits with AR technology enhanced the cognitive experience of the audience (Puig et al., 2020).

Multi-Sensory Learning Theory

Multisensory learning theory suggests that learners' knowledge acquisition and memory can be improved through visual, auditory, tactile, and kinesthetic stimulation (Fleming & Mills, 1992). Treichler (2018) states that "people typically remember 10% of what they read, 20% of what they hear, 30% of what they see, and 50 per cent of what is seen and heard at the same time." Neuroscience research also supports this theory, finding that multisensory input enhances neuronal connections and promotes the brain to encode and store information more efficiently (Maier et al., 2019). While some museums have begun to use AR to provide new cultural heritage experiences, such as the National Museum of Korea's use of AR docents to allow students to interact, many AR exhibits are still limited to simple viewing and are not effective in enhancing children's interest and learning. Such one-way information delivery makes it difficult to stimulate deep engagement and understanding. Museum education faces challenges in increasing young people's interest and engagement, and AR technology

demonstrates its potential. By integrating multisensory learning theories and developing a multisensory AR book, we aim to provide new approaches to museum education to enhance middle school students' understanding and memory of cultural heritage.

METHODS

This study used an integrated approach combining qualitative and quantitative methods to analyse the effects of a multi-sensory AR book on seventh-grade students' interest and emotional responses in museum learning and their academic performance in history. The qualitative part of this study followed Erlingsson and Brysiewicz's (2017) procedure for analysing qualitative data, drawing on Hsieh and Shannon's (2005) 'traditional content analysis', Elo and Kyngäs' (2008) "inductive content analysis" and Graneheim and Lundman's (2004) "qualitative content analysis of interview texts". Data analysis began with listening to the audio recordings of the interviews, which the researcher read several times to understand the participants' perspectives and ideas. Words, phrases, and passages were extracted from the transcription of students' experiences of AR library use, summarised and coded into units of meaning, and grouped according to core meaning. The research mentor (an experienced qualitative researcher) was involved throughout the data analysis process. At the same time, we also used the relevant history test questions from the first book of the 7th grade of the Humanities Teaching Edition as a measurement questionnaire, and the data analysis method of Ordinary Least Squares (OLS) was used to explore the impact of the use of multisensory AR books in museums on the learning outcomes of the history of the 7th grade students.

Sample

The subjects of this study were 31 seventh-grade students in two classes at a junior high school residing in northern China, and both classes were under the supervision of the same history teacher. The study was conducted at the Palace Museum in Beijing, China. Multi-sensory theory provided the theoretical basis for this study. The aims and objectives of the experiment were briefly explained to the students' guardians before commencement and the study commenced with the consent of their guardians.

Research Process

Pre-preparation for Developing AR Books

The data collection process began with in-depth interviews with museum history specialists to ensure that the direction and level of content development were appropriate for the target age group and to discuss the pros and cons of the real-life content currently on display for children and the values they wished to convey. Next, parent interviews were conducted to understand the expectations and needs of both children and parents. Finally, focus group interviews were used to further explore the application of multisensory learning theory to AR content development.

Book Structure and Content

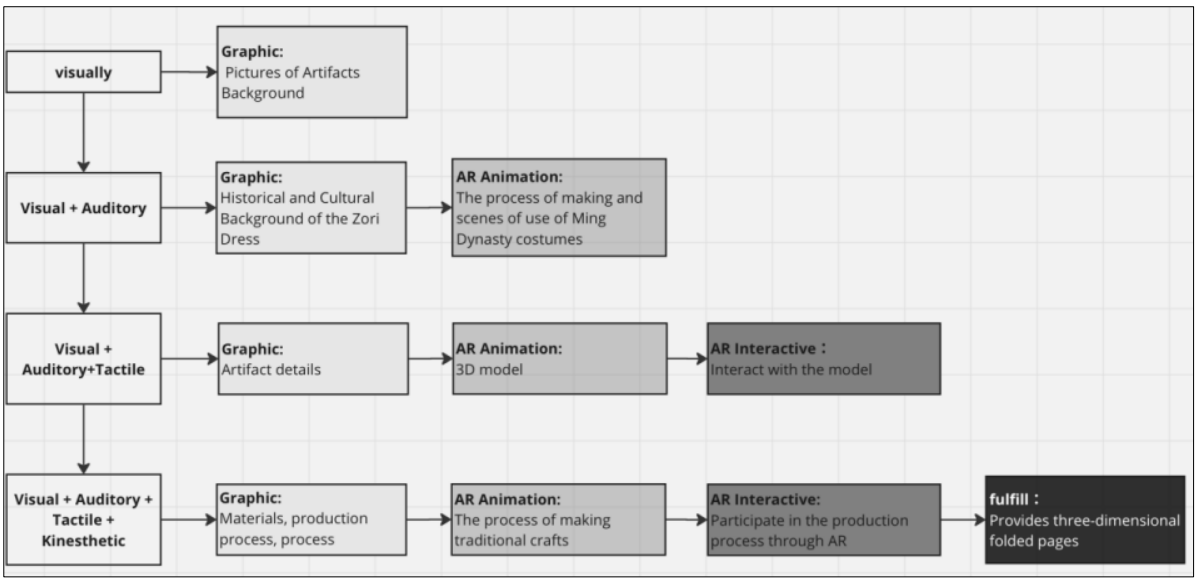

Figure 1. AR Book Multi-Layer Sensory

To explore my RQ1 the following are the specifics of my development of the book (refer with: Figure 2) How does a combination of multi-sensory experiences affect students' interest in learning and their emotional state of learning through a hierarchical and progressive combination of senses (refer with: Figure 1)?

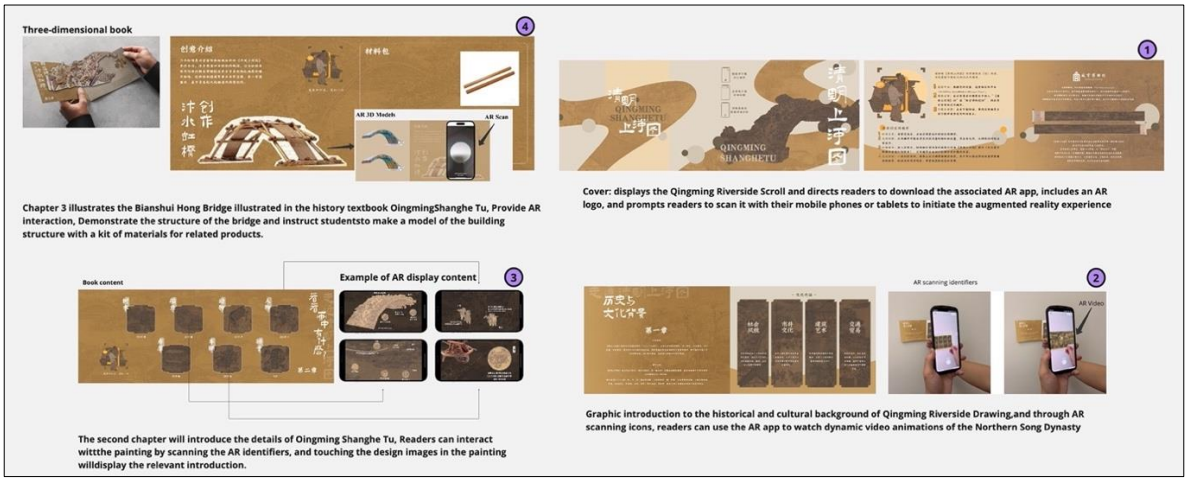

Figure 2. Details of The AR Book

The experimental design consisted of three levels of learning, each of which was evaluated with detailed exchanges of opinions and tests before and after use. The first level focuses on visual and auditory experiences, with video animations of the Northern Song Dynasty viewed through the AR app. The second level adds a haptic element where students can interact with the 3D model by scanning the AR logo. The third level adds a kinesthetic experience where students create architectural models guided by AR. Each level is designed based on multisensory learning theory, aiming to increase students'

learning interest and emotional response (refer with: Figure 3). Appendices and references provide detailed references and links to resources for further reading. Information about exhibitions related to the Forbidden City Museum is listed to encourage readers to visit the museum to experience and learn for themselves.

Figure 3. Students Making Architectural Models

Experimental Design

As shown in Figure 4, students were familiarised with the operation of the AR book one week before the start of the formal study to avoid operational problems. Fifteen minutes before the start of the formal study, participants were briefly introduced to the cultural assets and the experiment. All students took a pre-test before the start, after which participants were given pre-prepared AR books that were used at three levels and exchanged opinions after using the second, third and fourth levels respectively. The first interview focused on textbook content learning related to the Northern Song period, the second interview discussed feelings and thoughts after completing the Level 3 task, and the third interview discussed the advantages and disadvantages of using AR books versus traditional history textbooks. Finally, a history learning post-test was administered after students had finished using the AR books to test the impact of the AR books on student learning outcomes. Notably, an expert observation team was assembled for this study, including a museum history specialist, a child educational psychologist, and several middle school parents. Video equipment was used to record students' manipulative behaviours and interactions during the experiment, and the team of experts recorded students' performance and behaviours at all stages of the study and were responsible for three exchanges of views with the students.

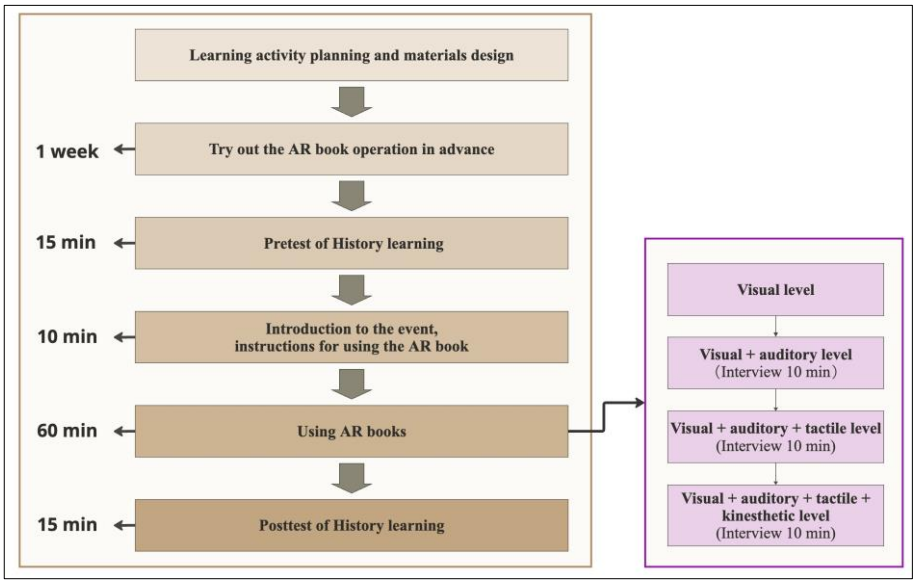

Figure 4. Experimental Procedure

Instrument

Based on the research objectives and research questions, the instruments used are described below:

Questionnaire for Testing the Level of Historical Knowledge

The test questionnaire used in this study was selected from the post-lesson exercise of the Chinese Ministry of Education's Humanistic Teaching Edition of the second year of junior high school history, Lesson 9, "The Northern Song Dynasty". The validity of the questionnaire was then verified by two history experts, two junior high school history special grade teachers and three junior high school history teachers with more than five years of teaching experience. The researcher screened and modified the test questions according to the research theme and designed them into three difficulty levels: basic examination, competency enhancement and in-depth explanation to test students' memory and understanding of the historical content. One point was awarded for a correct answer and zero for an incorrect answer, and the higher the total score, the more the students knew about the history of the Northern Song Dynasty. Questionnaires were administered before and after the experiment to assess the effect of the AR books on students' academic performance.

Interview Guide

Before data collection, an interview guide was developed to guide the participants in communicating in a way that allowed for flexibility in responding to the questions; the interview guide was designed to gain insight into the students' experiences and feedback during the use of the AR books. Each question was then assessed for clarity and relevance by four experienced researchers, including a museum history specialist, a child educational psychologist, and two qualitative researchers, which facilitated the process of refining the interview guide. The interview guide was then pre-tested with four seventh

graders to assess the applicability of the interview guide to seventh graders. It consisted of eight open-ended questions that allowed participants to discuss as many elements as possible.

FINDINGS

Analysis of Interview Results

Following the procedure of Erlingsson and Brysiewicz (2017), the content analysis identified nine categories under two themes, as shown in Table 1.

Table 1 *Results of The Qualitative Data Analysis*

Theme	Category	Code	Meaning units
Children's Reactions to Using AR Book	Curiosity	I haven't touched this before, and I'm curious.	"Is this AR? What is the principle?" "What should I do?" "I haven't been exposed to this kind of book before."
	Interest, motivation	I like it very much and am very interested.	"It turns out that learning history is so interesting!""I really enjoy this process. ""This is more interesting than classroom learning." "I want to take this book home." "Can I use it often?"
	Ask for help	I don't know what to do. Please help me.	"Is that right?" "How should I proceed to the next step?" "Please help me." "Do I need to scan this QR code with my mobile phone?"
	Emotional change	This kind of interesting book makes me very happy.	"I think this is super interesting." "Wow! I really didn't expect the book to move like this, great! ""This process seems to be playing games, and I am very happy."
	Immersive use of AR books	Although the process was difficult, I succeeded.	"Although the process was a bit difficult, I succeeded. ""I gained knowledge of history." "When using it, I think I am very serious."
Advantages Between Multi-Sensory Learning Forms and AR Content	Advantages of using multi-sensory learning form	This way makes me feel very involved, and different levels bring me rich experiences.	"Let me feel the lively scene of the city in China during the Northern Song Dynasty. ""Every level surprises me." "I remember this way of learning deeply." "I was very involved in the whole process."
	Advantages of using AR	Can let me know more about	"You rotate this model from different angles, and you can find something new every time.""I know what the handicraft industry is!"

continued

	book for learning	history from different angles.	
	Relevance to school classroom learning content	I studied this history in the school classroom.	"Isn't this just learned some time ago?""Their market in the Song Dynasty is quite like our current market!""Wow! This is the capital of the Northern Song Dynasty in our history class! "
	Motivation to continue studying in the future	I want to know more about this history of China.	"I want to study this history more in the future." "I want to know more about the historical heritage of our country." "I'm going to the museum to see this cultural relic for myself."

Children's Reactions to Using AR Books

The first theme focused on students' reactions during the use of AR books. Students showed strong curiosity, as they expressed their first exposure to this kind of book by saying, "I haven't been exposed to this kind of book before.", and their curiosity about the principles of AR technology and its use in building bridges in ancient China. In addition, students showed strong interest and motivation in using the book, often reacting with surprise and delight to the multi-sensory interactive elements (e.g., AR videos, building wooden bridges), "It turns out that learning history is so interesting!" "This is more interesting than classroom learning." which largely increased their willingness to learn (refer with: Figure 3). When difficulties were encountered, students sought help by saying "How should I proceed to the next step?" and "Please help me.", demonstrating that while they were eager and curious, they also sought guidance to fully understand and navigate the AR features and associated historical knowledge. This behaviour demonstrates a proactive approach to learning where students are motivated to overcome challenges, and this positive emotional response not only enhances their learning experience but also promotes a more immersive learning environment.

Advantages Between Multi-Sensory Learning Forms and AR Content

The second theme relates primarily to the advantages of multisensory forms of learning and augmented reality (AR) content. Students enjoyed the combination of visual, auditory, tactile and interactive elements that helped them to better remember and understand historical events and concepts. They reported that this multi-sensory approach to learning enhanced their understanding of history. In addition, the students felt that the AR books enabled them to learn history from a different perspective. One student mentioned, "You rotate the model from different angles and discover something new every time," highlighting the immersive experience that AR provides. Students also related what they learnt from the AR books to what they had learnt in their school history classes, making comments such as "Wow! This is the Northern Song capital city we learnt about in history class!" and "Isn't this something we've learnt before?" comments. This suggests that AR books provide a dynamic and interactive supplement to traditional textbooks, bridging the gap between theoretical knowledge and real-world applications. In addition, students expressed a strong motivation to continue learning about history,

saying, "I want to study this history more in the future," and "I want to go to a museum to see this artefact for myself."

Analysis of Academic Performance

In this section, Ordinary Least Squares (OLS) is used to analyse the effect of using multi-sensory level AR books in museums on the learning effectiveness of history for 7th-grade students. In this case, the Type of exam question is divided into four parts: Total score, Basic investigation, Ability improvement, and Deep discussion, and the changes in the values of the pre-test and post-test of each part are considered. The baseline regression results are presented in Table 2. In columns (1), (3), (5), and (7), the model does not incorporate individual fixed effects. Whereas in columns (2), (4), (6), and (8), the model incorporates individual fixed effects. The results demonstrate that all coefficients are significantly positive, indicating that students' use of AR books effectively improves their overall performance on the history knowledge test. Meanwhile, the scores of Basic investigations, Ability improvement, and Deep discussion were improved in all three question types. Based on the specific coefficients of the baseline regression results, it can be learnt that the student's total score improved by about 7.8 points after using AR books, the Basic investigation question type improved by about 2.267 points, the Ability improvement question type improved by about 4.133 points, and the Deep discussion question type improved by about 1.400 The score for the Deep Discussion question type increased by about 1.400 points.

Table 2 *Benchmark Regression Result*

Variables	Total score		Basic investigation		Ability improvement		Deep discussion	
D	7.800***	7.800***	2.267***	2.267***	4.133***	4.133***	1.400***	1.400***
	(7.455)	(26.253)	(3.968)	(12.665)	(9.679)	(19.918)	(5.541)	(15.389)
Individual fixation effect	N	Y	N	Y	N	Y	N	Y
Cons	8.633***	5.600***	4.400***	3.367***	3.467***	1.433**	0.767***	0.800***
	(11.670)	(6.770)	(10.894)	(6.757)	(11.480)	(2.481)	(4.291)	(3.159)
N	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000
R^2	0.481	0.958	0.200	0.921	0.611	0.908	0.335	0.914

Notes: *, **, and *** stand for significant at the 10%, 5% and 1% levels.

DISCUSSION

AR and VR technologies have the potential to reshape education by providing students with more engaging and immersive experiences (Algerafi et al., 2023). This study investigates the impact of the designed and developed AR book on junior high school students' learning interest and affective responses in museum learning, as well as the impact on student's academic performance in history,

using historical artefacts and knowledge of the Northern Song Dynasty in the Palace Museum as a backdrop. This study used both qualitative and quantitative methods to explore the impact of AR books on seventh-grade students' history learning. Analysis of interview content focused on students' interest in learning and affective responses to using augmented reality books, whilst quantitative analysis used Ordinary Least Squares (OLS) regression to measure the impact on student academic performance in history. Interviews revealed that students had a positive attitude towards using AR books and that the novelty of the technology fuelled their curiosity and excitement, and this initial curiosity translated into sustained interest and motivation. Secondly, the multi-sensory levels of AR videos and interactive activities surprised and delighted students, increasing their engagement and willingness to learn. Students demonstrated a positive attitude towards overcoming difficulties and a willingness to ask for help, suggesting that the AR books provided an interactive and immersive learning environment that helped them understand complex concepts more quickly. Students also later linked the AR books to classroom instruction and showed great excitement about identifying historical knowledge. Quantitative analyses showed that AR books not only enhanced students' historical knowledge, but also improved their critical thinking and analytical skills, which proved that AR books are effective tools in museum education and help to enhance students' academic performance in history.

CONCLUSIONS

By applying multi-sensory combinations of AR books in a museum environment, we explicitly answered the research question of whether such AR books can enhance students' learning and interest in learning. The results of the study show that AR books not only enhance students' historical knowledge, but also their learning interests and emotional responses. In addition, this study provides valuable practical and theoretical guidance for the field of history education.AR books, as an innovative educational tool, not only enhance students' academic performance, but also stimulate their interest in history. This finding has important implications for educators and museum educators, providing them with a new pedagogical approach to integrate AR technology in museum curricula to create more interactive and engaging learning environments. Although AR books have generally improved student learning, there are still some shortcomings in their practical application. For example, students need technical guidance in using AR books or they may encounter difficulties in operating them. In addition, the development of high-quality AR content requires a lot of resources and expertise, which may be a challenge for some museums and educational institutions. The shortcomings mainly stem from the limitations of technical support and resource allocation. Future research should be conducted in different types of museums and in more diverse educational contexts to validate the generalisability of the findings. There is a need to explore how AR technology can be effectively implemented with limited resources. Attention should also be paid to the impact of AR books on students of different ages and learning levels. Future research could further explore the use of AR technology in other disciplines and examine its long-term educational effects to provide more comprehensive guidance and support for educators and researchers.

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