Steam Learning in Virtual Reality for Cultural Heritage Promotion in Shek O, Hong Kong: Substitute or Complement for On-Site Field Trip?

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Abstract
This research focuses on utilizing a STEAM educational technique, specifically a VR website, to enhance the learning of cultural heritage in Shek O, Hong Kong. Shek O is a traditional village of cultural significance, attracting tourists and recognized as a heritage site. The study aimed to evaluate the effectiveness of the VR tool in terms of knowledge enrichment about Shek O's cultural heritage, attitudinal changes towards the site, and usability of the platform. The study included 50 local secondary school students who played the VR website before visiting the site (experimental group), while another 114 students solely engaged in VR learning without visiting the site (control group). Overall, the evaluation of the VR tool indicated above-average scores in terms of knowledge enrichment, attitudinal changes, and usability of the platform. However, when comparing the mean scores between the two groups, the results revealed that the group that experienced VR and visited the site achieved significantly higher scores in terms of knowledge enrichment, attitudinal changes, and perceived usability of the platform than those who did not visit the site. These findings suggest that combining VR with an on-site field trip can directly and positively influence user perception, while enhancing knowledge enrichment and attitudinal changes towards the cultural heritage of the site. These findings have meaningful implications for educators in utilizing VR for students' effective learning outcome.

Keywords: Virtual Reality, Youth, Fieldtrip, STEAM Education, Cultural Preservation

Introduction

With the emergence of advanced communication technology and e-learning, the availability of diverse media content, such as games, has revolutionized the learning experience for young learners. Game-based learning in cultural heritage education and tourism, as evidenced by studies such as Kalbaska & Cantoni (2022), has gained significant traction. A key outcome of e-learning is the heightened interest it generates among students, as highlighted by Shi et al. (2022) and Wronowski et al. (2020). In addition to various media content, the use of virtual environments has been extensively discussed in the literature. Scholars such as Lawson & Meyer (2024) and Liu et al. (2020) have explored the benefits of virtual environments in education. However, there is a knowledge gap regarding the effectiveness of combined e-learning approaches with on-site school fieldtrip. To bridge this gap, Chan et al. (2020) and Yu et al. (2021) conducted separate studies to investigate how the use of specific media content only, such as gaming, can enhance educational outcomes.

Game-based learning is often integrated into e-learning, which is defined as the use of diverse ICT and electronic devices in teaching (Maatuk et al., 2022). Within e-learning, the utilization of multi- and hyper-media provides limitless opportunities for learning. By integrating images, sounds, and videos with textual elements, it creates more engaging experiences and enables the inclusion of original documents, references to other sources, and the orchestration of multiple voices and perspectives (Kalbaska & Cantoni, 2022). Among the various e-learning tools, VR encompasses a range of technologies that offer immersive and interactive three-dimensional (3D) virtual environments, either based on reality or a fictional scenario (Mikropoulos & Natsis, 2011). VR allows for the creation of (hyper-) personalized learning experiences that are tailored to the explicit decisions, performances, and learning behaviors of individual participants. Moreover, non-immersive VR environments, predominantly displayed on conventional flat screens, can be arranged by designers to enhance the collective participation of participants within the same arena (Huang et al., 2021). In recent years, VR has been increasingly utilized in classrooms across various educational levels, from kindergarten to higher education (Merchant et al., 2014). This adoption has been particularly amplified during the COVID-19 pandemic when traditional educational methods were swiftly replaced by e-learning due to the risks associated with social gatherings in educational institutions (Maatuk et al., 2022).

One of the potential educational outcomes of VR is the simulation of on-site experiences (Gielstra et al., 2024), which can serve as a substitute for field trips. Field trips are considered essential components of education; however, their availability is often limited by geographical factors, as well as time and cost constraints (Jong, 2014). In reality, only a few students are granted the opportunity to participate in local field trips, and even fewer in non-local ones. With a simulated virtual environment, more students could be involved and benefit from receiving instructions from their teachers. Additionally, a wider range of destinations and sites for tourism teaching could be covered with less effort and constraints, such as weather. These are just a few advantages of utilizing VR to simulate on-site experiences in education.

This article investigates the extent to which e-learning techniques with VR can assist in education through virtual tours, potentially enhancing students' understanding of geography, culture, and cultural conservation in specific locations. The paper specifically focuses on indicators such as knowledge transfer, attitudinal influence, and platform usability to demonstrate the educational function of VR techniques in e-learning. To empirically

demonstrate the study, this paper refers to an ongoing VR development project related to e-learning and Shek O, a classic heritage fishing village in Hong Kong with over a hundred years of development history. The paper presents major observations on student users who participated in VR sessions and compares two groups: one with field trip experience and one without. The study aims to (1) evaluate the effectiveness of cultural heritage learning through STEAM education and (2) compare the knowledge enrichment on cultural preservation of Shek O, attitudinal changes on cultural heritage of Shek O, and perceived usability of the VR platform between the two groups, with one group visiting the site after the VR demonstration and the other group not visiting the site after the VR demonstration.

Literature Review

Learning Cultural Conservation From On-Site Experience

The conventional and unidirectional learning setting, such as one-way, one-instructor-to-many-learner, has received significant criticism for its ineffectiveness in teaching knowledge related to real-life geographical and cultural contexts, as this knowledge requires high involvement and interaction from students (Bikar et al., 2022; Burlingame, 2023; Yang et al., 2024). Many scholars focus on students' incentives as the key element of learning and aim to discuss the effectiveness of pedagogical approaches to enhance active learning (LaDue et al., 2022; Yang & Chen, 2022). However, the limitations of the classroom setting remain a significant constraint when learning practical experiences about real-world cultural and geographical situations. Therefore, some scholars argue that learning would fulfill the need for practical experience, especially for practitioners training in the industry (Cini et al., 2015). Internships and field trips, generally referred to as on-site experiences, are widely chosen in pedagogy as they can cater to the specific needs of studying geographical, cultural, and heritage settings, which often involve community-based topics and experiences (Kelner & Sanders, 2009). Students who participate in on-site experiences often view them as "eye-opening experiences beyond the learning modules of university-based theoretical viewpoints" (Ting & Cheng, 2017). When conditions and resources are sufficient, additional practicum or skill-based learning opportunities can also be provided (Howard, 2011). Previous studies have demonstrated that this type of learning experience can lead to attitudinal and behavioral changes in students (Kim et al., 2015), and these effects can be maximized through reflexive examination of students' experiences in post-experience assessments (Ting & Cheng, 2017).

Students who have engaged in hands-on experiences often describe them as enlightening encounters that go beyond the theoretical perspectives taught in university settings (Ting & Cheng, 2017). When adequate conditions and resources are available, it is possible to offer more opportunities for practical training or skill-based learning (Howard, 2011). Previous research has demonstrated that this type of learning experience leads to changes in students' attitudes and behaviors (e.g., Kim et al., 2015; Ting & Cheng, 2017). To maximize the benefits, educators should encourage students to critically reflect on their experiences after the practical training (Ting & Cheng, 2017).

Interestingly, cultural intimacy is also identified as a major outcome of on-site experiences when visiting cultural heritage sites, particularly in the context of cultural tourism or cultural preservation (Richards, 2018). On-site experiences allow visitors to fully immerse themselves in and learn about the community-based culture, enabling them to understand the significant value of a place based on their firsthand experiences. This immersive experience can provide a sense of depth and purposefulness to visitors' cultural motivation and acceptance

(McKercher & Du Cros, 2014). On-site experiences can have direct and indirect impacts on both visitors and the local community. For example, a study by Vong & Ung (2012) found that tourists experiencing heritage places in Macau could learn about Macau's history and culture through on-site heritage interpretation. As more visitors come to recognize the community as a valuable spot worthy of cultural preservation, it can even improve local people's attitudes towards preserving the cultural heritage (Jimura, 2011). These outcomes align with the factors listed by Loulanski & Loulanski (2011), highlighting how on-site experiences can facilitate local involvement and education among various stakeholders.

Learning Cultural Preservation From VR

While academic discussions on cultural preservation have shifted towards debates on the definition and authorization of "intangible cultural heritage" (e.g., Frey & Steiner, 2011; Van Dijk & Kirk, 2007), there is also a focus on how modern digital innovations can assist in heritage conservation and cultural tourism. Several studies have explored the use of digital tools and technological advancements in this regard (e.g., Bapiri et al., 2020; Fusté-Forné, 2019; Singh, 2020). Some studies discuss how new digital tools can help recreate a similar experiential feeling compared to on-site visits, particularly in light of the COVID-19 pandemic when physical on-site visits are no longer feasible (e.g., Lew et al., 2020). With the aid of technological advancements, new digital tools, such as VR techniques, have successfully simulated on-site experiences.

VR is increasingly being utilized in geography education, generating interest in its application. Shih et al. (2020) developed a mobile VR interface for exploring the cultural elements of Lukang in Taiwan, contributing to heritage preservation and cultural sustainability. Barbara (2022) implemented an immersive VR learning experience for 11 to 12-year-old history students, focusing on the intangible cultural heritage of the Maltese Neolithic hypogeum. Feedback surveys indicated positive responses regarding authenticity, ease of navigation, learning outcomes, and classroom utility. These findings align with Checa & Bustillo's (2019) study, where undergraduate students found VR effective for learning about the cultural heritage and history of Briviesca. However, Daniela & Aierken (2020) noted that while VR has the potential to revolutionize education by enabling experiences that are not feasible in the real world, it is crucial to prioritize educational objectives in VR learning. While VR offers a wide range of possibilities, there is a need to strike a balance and ensure that the focus remains on meaningful learning rather than being solely captivated by the technology itself. Studies, such as Li et al. (2020), have noted that some Hong Kong students may become overly excited about VR technologies, which could potentially be counterproductive to their learning outcomes.

The innovation of VR in cultural heritage education reopens the discussion on e-learning: Can VR help young audiences have enriched or even create virtual on-site experiences? And is the effectiveness of the VR experience similar to real-life experiences? The first question seems to be supported by a series of academic research. Online technology is often developed to overcome educational limitations, especially when the subjects involve real-life examples in geography and environment-related content (Howard, 2011). Many studies have also revealed that students are more enthusiastic about and satisfied with collaborative learning using advanced technology (e.g., DeLozier & Rhodes, 2017; McNally et al., 2017). In terms of VR techniques for cultural heritage education and tourism, scenario-based simulations have been added to visualize key elements in real-world conditions and field trips within V-learning-based platforms and classroom lectures (e.g., Cini et al., 2015; Kelner & Sanders,

2009; Ting & Cheng, 2017). Such platforms can be beneficial for teaching, particularly in institutes with limited resources to arrange field trips and practical experiences (Howard, 2011).

The integration of VR in cultural heritage learning has sparked discussions about its potential impact on e-learning. Scholars have explored whether VR can provide young audiences with enriched or simulated on-site experiences and whether the effectiveness of VR experiences is comparable to real-life experiences (Schott, 2017). Research suggests that online technologies are often used to address educational limitations, especially in subjects involving real-life examples in geography and environment-related content (Sedlák et al., 2022). Studies have also demonstrated that students exhibit greater interest in and satisfaction with collaborative learning using advanced technology (DeLozier & Rhodes, 2017; Herbert et al., 2017). In the context of cultural heritage education, VR techniques, such as scenario-based simulations, have been employed to visualize key elements in real-world conditions and field trips within virtual learning platforms and classroom settings (Cini et al., 2015; Herbert et al., 2017). This approach has proven beneficial for teaching, particularly in institutions with limited resources to organize physical field trips and practical experiences (Mavridis et al., 2017). These findings support the notion that VR can offer young learners virtual on-site experiences that are immersive and comparable to real-life experiences, enhancing their engagement and understanding of cultural heritage.

However, the second question regarding the comparison of "real/virtual on-site experience" remains uncertain. While it is often recommended to compare the learning experience and effectiveness between traditional classroom learning and e-learning (DeLozier & Rhodes, 2017), there is limited research that directly compares e-learning to on-site learning experiences. Instead, some studies have focused on evaluating the risks and reliability of virtual platforms, as the informality of learning instruments may cause anxiety among students (Howard, 2011). However, some studies explore different indicators to measure the effectiveness of learning from on-site experiences, such as the development of a broader global consciousness and a better understanding of cultural diversity (e.g., Raptis et al., 2018). Despite a relatively limited literature, there has been debate among scholars, whether the VR fieldtrip can serve as a substitute or complement to the on-site fieldtrip (e.g., Spicer & Stratford, 2001; Patiar et al., 2017). Hence, there is still a significant gap in empirical evidence regarding whether virtual STEAM will replace or complement on-site fieldtrip in relation to students' learning of cultural conservation.

Based on the aforementioned studies, this project aims to address two research questions and hypotheses. The research questions are as follows: (1) What is the effectiveness of STEAM education in enhancing students' performance in cultural preservation? and (2) How do the learning outcomes of students who engage in STEAM educational outcomes differ between those who attended the site and those who did not? The corresponding hypotheses for these research questions are as follows:

H_1: There is an above-average feedback on students' perception of the effectiveness of STEAM education in enhancing students' learning in cultural preservation.

H_2: Students who have experienced STEAM education coupled with on-site visits demonstrate higher effectiveness of STEAM education compared to those who have only received STEAM education without the on-site experience.

Methodology

Based on the above discussion, the study aims to (1) evaluate the effectiveness of student in STEAM education of (i) knowledge enrichment, (ii) attitudinal changes and (iii) usability of the VR platform as part of the perceived learning outcomes. The study also shed light on (2) comparing the users' ratings with or without additional on-site experience, which could see whether VR platform could assist or even replace the on-site experience in understanding cultural preservation.

There are numerous cultural spots being preserved in different ways across Hong Kong. For example, Gallagher (2021) discussed the adaptive reuse of the historic Tai O Police Station in Hong Kong. Museums like the Hong Kong Heritage Museum have played a crucial role in showcasing Hong Kong's cultural heritage to the wider public (Henderson, 2001). With the advancement of technology, there has been an increasing use of technologies in preserving local cultural heritage, particularly in the promotion of education through VR for students.

Shek O, a fishing village in Hong Kong, has undergone development for over a century, particularly during the British colonial rule. As part of our study, we have developed a VR experience that allows users to virtually explore Shek O and gain a deeper understanding of its cultural heritage. Shek O serves as an exemplary case of heritage tourism, where on-site experiences play a significant role in promoting heritage conservation. In this context, tourism acts as a catalyst, actively contributing to the preservation of the heritage site. Scholars like Lussetyowati (2015) envision various benefits, including revenue generation, arising from such conservation efforts. To support the conservation of Shek O, we have engaged volunteers from the local community who are knowledgeable about the cultural heritage of Shek O. During school visits, these volunteers introduce the VR experience to the audience and share insights about Shek O's cultural heritage. The audience is provided with the opportunity to interact with the VR, which presents a map of Shek O. Users can virtually navigate the village, clicking on various points of interest to listen to stories shared by local residents pertaining to the cultural heritage of specific sites across Shek O.

Due to budget constraints, the study invited two schools to participate in the VR-learning program focusing on the cultural heritage of Shek O. One school was assigned to take part in a site visit to Shek O after the students had the opportunity to experience the VR as part of their curriculum. The target group for this experimental group consisted of 50 participants. The other school, serving as the control group, had students watch a VR demonstration only in a classroom setting. The control group consisted of 114 participants. All participants were aged between 10 and 15 and belonged to the two participating schools.

We conducted a survey using the same set of survey questions for both the experimental and control groups. The survey utilized a Likert scale ranging from 1 (disagree) to 5 (agree) to assess the participants' responses regarding their learning outcomes. The survey included questions that aimed to measure the participants' agreement on the following aspects of the VR learning experience: i) knowledge enrichment, ii) attitude changes, and iii) usability of the VR platform. In educational research, student performance is often evaluated based on independent variables related to knowledge, attitude, and behavior (Chan et al., 2020). Hence, we conducted a comparison of the mean values on the eight survey items between the control and experimental groups. This comparison allowed us to assess whether the VR platform resulted in differences in learning outcomes. Our study takes a modified approach by focusing on evaluating the effectiveness of the learning experience within a cross-sectional

timeframe, rather than examining long-term changes in student behavior. The primary objective is to evaluate the satisfaction and effectiveness of the learning experience using VR, considering three independent variables.

The first independent variable focuses on evaluating the extent to which students' knowledge is enriched through the use of VR learning in an urban tourism scenario. Previous studies provide insights into this aspect. Liu et al. (2020) conducted a study that demonstrated significant improvement in examination scores among students who utilized an advanced technology platform, indicating the potential for substantial knowledge acquisition. Li et al. (2022) conducted a study specifically examining the relationship between groups of Chinese university geography students who used VR and those who did not use VR in understanding geography academic terms in English language. The results indicated that the experimental group, which utilized VR, demonstrated superior performance compared to the control group in terms of incidental vocabulary acquisition.

The second independent variable focuses on evaluating the impact of VR learning on students' attitudes and affective learning outcomes (Shephard, 2008). Nikolaou et al. (2022) conducted a systematic review that demonstrated the positive effects of VR on attitude change among users or learners. The majority of the studies included in the review reported that the use of VR enhanced social attitude change compared to groups that did not utilize VR. Existing studies, such as Menzel et al. (2014), have also highlighted the positive impact of VR on attitude change, which students who were exposed to VR experiences aimed at understanding social issues like poverty showed higher scores in positive attitude change towards the poor compared to the control groups.

The last independent variable in this study focuses on the usability of the VR platform. Webster (2016) emphasized that while digital platforms can enhance learning immersion, interaction, and motivation, they cannot fully replace an instructor in the classroom. Usability and achieving specific goals are important considerations for innovative educational models (Alhamad et al., 2023; Xu et al., 2017). Contextualizing knowledge extraction within a local setting is crucial for a quality learning experience (Efstathiou et al., 2018). These studies underscored the impact of the design quality of e-learning platforms on overall satisfaction with the learning experience.

Results

The results are presented in two parts. Firstly, we conducted a descriptive analysis of the survey responses. The items in the survey were numbered, and they aimed to assess the respondents' agreement regarding various aspects of the VR learning experience. These included: 1) enhancing understanding of Shek O culture. 2) improving knowledge of Shek O geography, 3) cultivating cultural interest towards Shek O, 4) Increasing willingness to visit Shek O, 5) perceiving VR as a means to preserve Shek O culture, 6) evaluating the effectiveness of VR documentation of Shek O, 7) assessing the potential for publishing Shek O content derived from VR and 8) exploring the role of VR in sparking cultural interest. Items 1-2 focused on knowledge enrichment, aiming to measure the extent to which the VR experience improved the respondents' understanding of Shek O's cultural and geographical aspects. Items 3-4 and 8 delved into attitude changes, seeking to gauge the impact of VR on fostering cultural interest and influencing the willingness to visit Shek O. Lastly, items 6-7 examined the usability of VR technology, assessing its effectiveness in documenting Shek O and the potential for publishing the content generated through VR.

The findings from the analysis indicate that item 1, 8, and 6 obtained the highest scores, ranking first, second, and third with values of 4.0427, 4.0061, and 3.9939, respectively. However, no significant differences were observed in the mean scores among the remaining items. Nevertheless, the overall results demonstrate that all the items across the three criteria scored above the average score of three. This suggests that VR effectively meets the perceived learning outcomes of the students.

Table 1. Descriptive statistics

Item no.	Items	Mean score^	Standard Deviation
1	Shek O Culture	4.0427	0.9023
2	Shek O Geography	3.8232	1.06210
3	Shek O Cultural Interest	3.9512	1.0497
4	Visit Shek O	3.8293	1.1275
5	Shek O Cultural Preservation	4.0061	1.0242
6	Shek O Documentation	3.9939	0.9688
7	Shek O Publication	3.9207	1.0331
8	VR Cultural Interest	3.8841	1.1533

*Range is from one (lowest score that the respondents agree) to five (highest score)

However, when comparing the control and experimental groups, the results indicate significant differences between the two groups. Across all eight items, the experimental group consistently achieved higher scores compared to the control group. Notably, the experimental group obtained the highest scores for items 1, 4, and 8, with respective scores of 4.4800, 4.5400, and 4.500. On the other hand, the control group achieved the highest, second highest, and third highest scores for items 1, 6, and 5, respectively. These findings highlight that, in all aspects, the experimental group exhibited superior self-perceived learning outcomes compared to the control group, which only watched the VR demonstration.

Table 2. Descriptive statistics between the experimental and control groups

Item no.	Items	Group	Mean score^	Standard Deviation
1	Shek O Culture	Control	3.8509	0.9707
		Experimental	4.4800	0.5047
2	Shek O Geography	Control	3.6842	1.1546
		Experimental	4.1400	0.7287
3	Shek O Cultural Interest	Control	3.7456	1.1195
		Experimental	4.4200	0.6728
4	Visit Shek O	Control	3.5175	1.1767
		Experimental	4.5400	0.5425
5	Shek O Cultural Preservation	Control	3.7895	1.0515
		Experimental	4.5000	0.7627
6	Shek O Documentation	Control	3.7895	1.0260
		Experimental	4.4600	0.6131
7	Shek O Publication	Control	3.6842	1.0834
		Experimental	4.4600	0.6456
8	VR Cultural Interest	Control	3.5965	1.22452
		Experimental	4.5400	0.5789

*Range is from one (lowest score that the respondents agree) to five (highest score)

Discussion

Generally speaking, in line with previous studies (e.g., Mavridis et al., 2017), our findings suggest that VR can be a valuable tool for teaching students about specific sites, particularly when schools face limitations in terms of resources and the ability to conduct field trips. By utilizing VR technologies, schools can virtually transport their students, overcoming the constraints of time and space, and allowing them to explore and learn in a virtual environment. This approach is particularly beneficial for subjects that involve real-life examples in geography and content related to the environment (Sedlák et al., 2022). The use of VR offers students the opportunity to interact with virtual environments, facilitating cognitive engagement with learning materials and improving comprehension of complex and abstract concepts through immersive and interactive scenarios (Lin et al., 2024). In the context of enhancing students' understanding of the geography and culture of Shek O, these findings highlight the potential of VR to provide an enriching and immersive learning experience.

The users' positive attitude changes towards Shek O can be attributed to the immersive nature of VR, which evokes a heightened sense of realism and engagement. When users are immersed in virtual environments, they develop more favorable attitudes towards the destinations depicted in VR. Consequently, these positive attitudes significantly influence users' intention to visit the showcased destinations (Tussyadiah et al., 2018). Regarding the usability of VR, learners are able to effortlessly navigate and interact with virtual environments, leading to increased engagement and improved understanding. The presence of intuitive controls, concise instructions, and seamless interactions within the VR environment allows learners to focus on the educational content, overcoming any challenges posed by technical intricacies (Özgen et al., 2021; Ramadhan et al., 2022). This is evident in the findings, as the items falling under the usability criterion have scored similarly to the other items related to knowledge acquisition and attitude change. Yet, students who went on the on-site field trip to Shek O, and who generally perceived better knowledge acquisition and attitude change towards Shek O cultural heritage from this learning activity, would also perceive that the VR technology being complemented with the field trip can help them improve their educational outcomes.

However, our results indicate notable differences in learning outcomes when comparing the group that only experienced the VR demonstration with the group that had both the VR demonstration and an actual visit to Shek O. The latter group achieved better scores in all aspects of learning outcomes. The virtual field trip through STEAM education, as perceived by students in previous studies, may not serve as a substitute for the on-site field trip. Instead, the virtual field trip can complement the on-site experience (Spicer & Stratford, 2001). By utilizing hypermedia programs, students have the opportunity to explore the site at their own pace, gaining better familiarity and enabling them to delve deeper into previously covered material, ultimately filling any gaps in their understanding. This approach enhances the value of on-site field trips by allowing students to maximize their overall experience and make it more rewarding (Patiar et al., 2017; Spicer & Stratford, 2001).

However, those who only utilized the virtual field trip may lack the interactive experience and direct contact with the site that the group visiting Shek O in person would have. The latter group would have the opportunity to navigate through different locations in the real world, providing a more comprehensive sensory experience involving all five senses. Virtual visits may not fully immerse students in real-life contexts, as certain topics may present

obstacles for students to fully engage their senses, as highlighted in other studies (e.g., Leininger-Frézal & Sprenger, 2022). This lack of complete sensory immersion in virtual visits could contribute to the control group scoring lower in terms of perceived knowledge acquisition and attitude change. They may perceive that VR cannot deliver better educational outcomes compared to the on-site setting.

Conclusion

Overall, our findings clearly indicate that incorporating virtual field trips alongside traditional on-site field trips would be the most effective approach for enhancing students' learning outcomes. Virtual field trips offer distinct advantages in terms of accessibility, flexibility, and exposure to diverse environments. However, they cannot entirely substitute the immersive and tangible experiences provided by on-site fieldtrips. Therefore, educators should consider utilizing VR as a complement prior to arranging on-site field trips, ensuring that students can achieve optimal learning outcomes.

Nonetheless, our study does have certain limitations. Firstly, there is an uneven distribution of students between the control and experimental groups, which is beyond our control as the groups are derived from different schools that agreed to participate with varying numbers of students. This introduces the possibility of baseline differences in student characteristics between the two groups, potentially affecting the statistical power of our analysis. Future research should aim to achieve a more balanced representation of students in both groups to ensure better comparability and statistical power. The second limitation is the reliance on self-report measures through surveys, which may result in a discrepancy between actual behavior and self-reported responses. To gain a more comprehensive understanding of the impact of VR and on-site field trips in education, future research could consider incorporating interviews with relevant stakeholders. Thirdly, our study design is cross-sectional, limiting our ability to establish causality. To address this limitation, future studies could incorporate pre- and post-field trip survey assessments to examine better the changes in learning outcomes among participants over time. Nevertheless, this study serves as an initial exploration into the impacts of VR on the learning outcomes of field trips. It provides a starting point for further research in this area.

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