A Review of Virtual Field Trip Applications in Construction Education

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ABSTRACT

The construction field trip is an interactive and essential component of construction education, and its significance is widely recognized by educators and researchers in the construction domain. However, due to its real-world nature, there are several challenges that limit the extensive employment of this teaching approach. A few examples of such spatiotemporal challenges are time conflict, large class sizes, short site visit duration, and not being able to see or hear in a crowded or noisy environment. Construction educators and researchers have been using virtual field trips to support traditional field trips or offer an alternative when these learning opportunities are not available. This paper presents the current status of virtual field trip application in construction education while specifically focusing on the construction subject areas, technology use, and learning assessment techniques used in those virtual field trips. The review shows that VFT has been mostly integrated with construction courses in fundamental and introductory level, and their learning objectives are mainly general and broad without a specific focus on certain construction aspects or techniques. The technologies to develop VFTs can be categorized into captured-reality using regular or 360 images or videos and virtual reality using computer-generated simulation of reality. Advantages and disadvantages of both technologies are discussed. Interview and questionnaires were mainly used to assess the reviewed VFT as a learning tool, and it is reported that in the majority of those papers, the feedback from students is mostly positive. These outcomes provide construction educators and researchers insights on successful implementation and potential challenges of virtual field trips in construction education.

INTRODUCTION

A construction field trip or site visit is an interactive experience to help students comprehend construction working procedures in a real-world setting, through exposing them to different spatiotemporal contexts on construction sites (Eiris and Gheisari, 2017). In a typical field trip, students are transported to real construction sites to meet project personnel and observe the dynamic construction processes onsite (Mills et al., 2006; Murray and Tennant, 2016). Field trip can support students' technical and practical engineering knowledge and aid them to reinforce the core concepts taught in class (Arslan, 2003; Eiris and Gheisari, 2018). By observing a real construction context, students can gain a spatiotemporal awareness which plays a critical role in the learning process (Milles et al., 2006). Meanwhile, this method gives students opportunities to communicate with professionals from architecture, engineering and construction backgrounds, and increase the awareness of available career options (Lave and Wenger, 1991; Adedokun et al. 2012; Murray and Tennant, 2016). However, along with all the advantages that make field trips attractive for educators and students, there are great amount of spatiotemporal and logistic challenges that limit the integration of the field trips with the curriculum. Time conflict with other classes, large class sizes, not being able to see or hear in a crowded or noisy environment, short duration of a trip are some of the significant barriers that hinder educators to organize a field trip (Erisi and Gheisari, 2017). These factors may also have a negative effect on the communication between students and professionals, and ultimately limit the amount of practical knowledge that students can gain onsite (Haque et al., 2005). Furthermore, high traveling cost and the dangerous environment are also widely recognized barriers that limit the inclusion of field trips in the university curriculum (Arslan, 2003; Haque et al., 2005; Jaselskis et al., 2010; Landorf et al., 2015; Pham et al, 2018; Quinn et al, 2019). From all these common limitations reported by researches, it is notable that many barriers are decided by the complexity of the real world, and solutions are also limited due to inevitable spatiotemporal constraints.

To overcome barriers of traditional field trips, researchers have explored virtual field trips (VFTs) which provide an easier access to the construction sites compared to traditional trips (Stoddard, 2009). VFTs refer to an experience of observing the physical conditions of a construction project via the Internet or other technologies (Finch and Wing, 1996; Jaselskis et al. 2010). VFT provides an experiential learning environment that can be accessed anytime anywhere by students (Eiris and Gheisari, 2018). Since a VTF is "a journey taken without actually making a trip to the site" (Woerner, 1999), challenges associated with the spatiotemporal constraints in real world are effectively overcome. Therefore, VTF is a promising educational method to support traditional field trips or offer an alternative when these learning opportunities are not available. Despite the advantage of VFTs, there are only a few reported applications in the construction management curriculum (Erisi and Gheisari, 2017). This indicates a lack of understanding about the potential of VFTs in construction education. The lack of technological support associated with VFT development may further hinder construction educators to apply a VFT. In this study, the authors conducted a literature review regarding the applications of VFT in construction education to better understand the following questions:

- *What are the subject areas and learning outcomes of construction curriculum that employ VFT?*
- *What are the technologies that have been employed to create VFT?*
- *How are these applications of VFT assessed?*

RESEARCH METHODOLOGY

This study conducted a content analysis-based literature review to analyze manuscripts and synthesize the outcomes. This method is widely applied to address broad research questions (Siddaway, 2014; Li et al., 2018). In order to locate the publications relevant to the scope of this research, keywords were generated to constrain the literature search. For example, the word "Virtual" was contained all the time to ensure all searched publications were applying certain technologies to simulate a trip instead of conducting a real trip. Several strings were used to identify the research topic in the scope of field trips, including "field trip", "site visit", "walkthrough", "work-integrated learning" and "experiential learning". A searching phase was conducted on two popular sources of scientific information in biomedical sciences, Web of Science and Google Scholar (Falagas et al., 2008), and following research databases: American Society of Civil Engineering, American Society for Engineering Education, and Elservier. The results of the literature search were systematically screened, identified, reviewed, and the publications outside the scope of this study were excluded. Finally, the 16 included manuscripts were analyzed based on the following taxonomy: the application area and learning outcomes of VFTs, the applied technologies, and the employed learning assessment techniques that evaluate VFTs as a learning tool. Architecture, civil engineering and construction management areas are not entirely independent fields in many colleges and universities. In other words, the VFTs designed for one field might benefit the other ones. Therefore, the searching scope of this study is not strictly constrained to construction management but also includes civil engineering and architecture for further analysis.

APPLICATION AREAS OF VFT

The application areas and learning outcomes of VFTs are introduced in this section. The application areas briefly reveal how the applications of VFTs were distributed in AEC relevant fields. Learning outcomes associated with VFTs were also identified and summarized in this section. This study found that VFT has been applied in all three fields (architecture, civil engineering, and construction management). Construction management has the most significant proportion of applying VFTs among these fields. This may suggest that field trips as an educational tool is more emphasized in the construction management curriculum.

Regarding the learning outcomes that are associated with VFTs, some were set in a relatively general and broad manner. Such learning outcomes include familiarizing students with the built environment disciplines, helping students realize the complexity of the construction sites, and enhancing students' understanding of different construction structures. VFTs that produce these learning outcomes usually allow students to observe random activities, structures and operations on a construction job sites (Finch and Wing, 1996; Mei and Wing, 1999; Wilkins and Barrett, 2000; Arslan, 2003; Dickinson et al., 2004; Jaselskis et al., 2010; Jaselskis et al., 2011; Landorf et al., 2015; Landorf and Ward 2017; Zhang et al., 2017; Amir et al., 2018; Quinn, Cioffi, and Hill 2019). This type of VFTs is usually set for courses at an introductory and fundamental level. Since there is little emphasis on specific construction aspects, working progresses, or operations in these VFTs, the difficulty of selecting a suitable construction site (or creating a virtual site) is relatively low. When VFTs are designed for this level of learning outcomes, it is found that there are considerable similarities between different VFT applications. To be specific, the authors observed many applications with this type of learning outcomes used a combination of both regular or 360-degree images and videos of a real construction site and delivered them in certain orders via Internet to simulate a field trip (Finch and Wing, 1996; Mei and Wing, 1999; Wilkins and Barrett, 2000; Arslan, 2003; Dickinson et al., 2004; Jaselskis et al., 2010; Jaselskis et al., 2011; Landorf et al., 2015; Quinn, Cioffi, and Hill 2019). If educators intend to apply VFTs to achieve fundamental and general learning outcomes, there are available VFTs developed by previous researchers which educators can directly benefit from.

On the other hand, some learning outcomes were set for specific curricula, such as construction safety (Haque et al., 2005) and Heating, ventilation, and air conditioning (HVAC) systems (Shen et al. 2012). Some learning outcomes were set for specific construction techniques, such as wood frame construction (Pham et al. 2018) and reinforced concrete construction techniques (Lucas 2018). In these cases, the selection of suitable job sites may require much more efforts to ensure VFTs are properly tied to the specific learning outcomes. For example, in Lucas (2018) research, one of the primary learning outcomes was that students should understand wood frame construction techniques and processes, particularly in terms of construction assembly. This learning objective requires a specific project that applies wood frame structures, and the VFT should be designed at a proper working phase. Only in this way can students have opportunities to observe the materials, components, and assembly sequence during the trip. This type of learning objective is usually customized for specific higher-level courses, which could not be shared by multiple courses at different levels and with different concentrations. From the analysis, it was noticed that when designing VFTs with specific learning outcomes for certain courses, researchers tended to create a virtual construction jobsite using 3D models. This way, they had better control over the environment of a construction job site (Shen et al. 2012; Zhang et al. 2017; Maghool 2018; Lucas 2018). Educators who need specific learning outcomes in their courses should consider using properly designed and developed VFTs, which is appropriately associated with their course contents and learning objectives.

TECHNOLOGIES

Technologies are classified into two completely different categories: captured-reality using images or videos and virtual reality (VR) using computer-generated simulation of reality. The most fundamental difference between these two types of technologies is the environment in which VFTs are developed. To apply captured-reality technology, researchers use regular or 360-degree images and videos obtained from real-world projects to create a platform for students to observe spatiotemporal contexts on site. On the other hand, VR technology relies on an entirely computer-generated virtual environment where users can manipulate and interact with objects (Warwick et al., 1993; Briggs, 1996). In other words, researchers create a 3D virtual construction job site for students to visit. Advantages and disadvantages for both technologies are introduced in this section, and typical examples are introduced in detail. The results can help educators and VFT designers to understand the characteristics of applied technology, so that they can decide which type of technology might better suits their courses and learning outcomes.

Captured-reality technology

The captured-reality technology is used to simulate a traditional field trip: it enables students to visit a real construction site virtually. Two different methods were used to capture reality in the reviewed articles: pre-captured and real-time methods. The pre-captured method indicates that the site visits content has been captured onsite before students taking the VFT. On the other hand, when using a real-time method, students experience a live VFT.

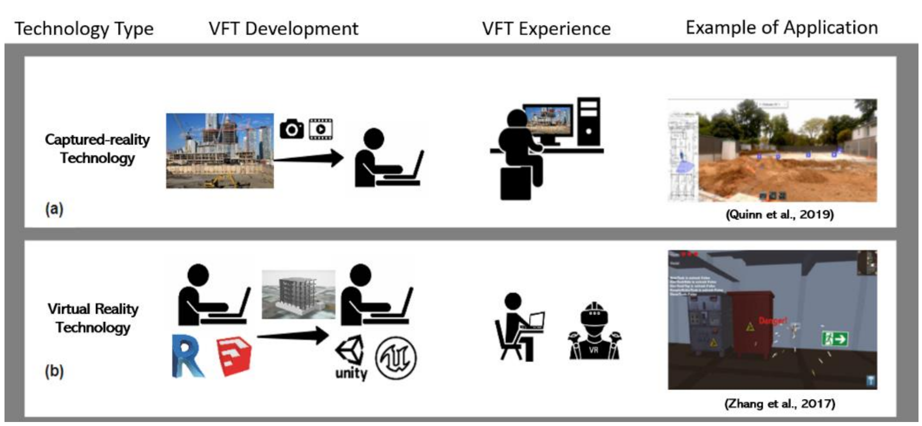

Figure 1. An overview of technologies applied in developing VFTs

The identified basic workflow behind the pre-captured method of creating VFTs is to (1) capture virtual tour materials on site; (2) deliver them in an orderly manner mainly via Internet (Finch et al. 1996; Mei and Wing 1999; Wilkins and Barrett 2000; Dickinson et al. 2004; Haque et al. 2005; Landorf et al. 2015; Landorf and Ward 2017; Quinn et al. 2019). Based on various functions developed on webpages, students may have different ways to operate the web-based VFT applications. For example, Quinn et al. (2019) firstly captured high-resolution 360-degree panoramas and regular images onsite. Meanwhile, videos of professionals explaining construction processes and materials were also collected. The 360-degree panoramas were used to create the main spatiotemporal context for students to observe during the VFT. Augmented videos and images on those pre-captured 360 panoramas were used to create an interactive field trip experience for students. A small job site plan was incorporated to help students gain a sense of feeling of the space. Like a real field trip, students could visit multiple locations during the VFTs. When students entered this web-based construction site, they could observe the overall environment by dragging the 360-degree panorama. To fully understand the information delivered in the current location, students could click on the available video to watch relevant construction processes and details.

The second way of applying captured-reality technology is to deliver the site visit to the students in real-time. In this method, VFT can deliver real-time images, videos and audio from ongoing construction projects to the students (Arslan, 2003; Jaselskis et al., 2010; Jaselskis et al., 2011). For example, Arslan (2003) created a website to deliver a real-time feed of a construction project using multiple cameras installed on the jobsite. Students were able to control the cameras via computer and watch the construction processes in real-time and also capture images to their local computers if needed. In another set of studies conducted by Jaselskis et al. (2010) and Jaselskis et al. (2011), a significant improvement to real-time video feed was made by enabling real-time communication between students and construction personnel on site. In these specific examples, one of the construction personnel, who wore a microphone-embedded headset and held a camera, needed to walk in a designated jobsite and provide details about construction activities and project details. The video imagery and voice information were transferred to the classroom in real-time via wireless internet. The classroom was equipped with a desktop computer to receive video imagery from the construction site, a video projector to enlarge the images, a speaker to ensure the audio was clear and loud enough to be heard by students and several microphones were distributed in the classroom to collect questions from the students in real-time. Although communicating with construction personnel is an outstanding advantage of this live-streaming method, the high-volume of background noise caused by construction operations and wind reduced the quality of the verbal communication between the construction personnel and students (Jaselskis et al., 2011).

The primary advantage of the captured-reality technology is that it uses images and videos of a real construction site to simulate a real-world field trip with the highest level of realism. It can help students familiarize with the actual construction sites and better visualize real-world construction processes. Since the virtual trip materials are captured directly from a real construction site, every detail and construction operation happening at that time are recorded in the VFT. When students are taking a VFT, they can gain a comprehensive understanding of the complex nature of a construction site. Furthermore, this technology may provide students with communication opportunities with professionals onsite. However, given the fact that most materials used to create VFTs are pre-captured or delivered in real-time, there is little possibility for students to explore the construction site freely; such limited interactions with the site make the learning process passive as these VFTs do not actively engage students in activities (Pham et al. 2018).

Virtual reality technology

Different from the captured-reality technology, where the overall platform of the VFTs is based on pre-collected or real-time captures of real projects; VR technology provides students with a simulated environment where they can freely navigate around and observe 3D objects from different angles (Warwick et al., 1993; Briggs, 1996). The VFT platform in the reviewed articles were mainly developed using the following two steps: (1) creating 3D models used in the field trip; (2) developing the VR experience using a game engine. In the first step, different 3D modeling software packages such as Revit (e.g., used by Shen et al., 2012; Zhang et al., 2017;) or SketchUp (e.g., used by Maghool, 2018; Lucas, 2018) were used to create desired models. Creation of details was tied to specific learning outcomes and content requirements of the field trips. In the second step, a game engine, Unity (e.g., used by Zhang et al., 2017; Lucas, 2018) or Unreal (e.g., used by Maghool, 2018), is used to create the VR experience. A game engine is a software development environment for game developers to design and build games, simulations, and visualizations. This step enables users to navigate inside the models and interact with objects using an easily controlled approach, such as mouse-clicks, keyboard-inputs, or game controllers. Since VR technology enables various input forms, the approaches to interact with the virtual construction sites are various and rich. Many activities that are tied to specific learning outcomes can be designed by the educators and developers in such VR field trips. Zhang et al. (2017) developed a safety task module in their virtual construction site visit game that assigns different tasks for students to accomplish. For instance, they have developed a task associated with fall and electricity hazards, which required students to remove safety hazards onsite and identify prevention approaches. In order to accomplish a task, students needed to examine different hazards in the virtual jobsite, answer relevant pop-up questions, and select specific tools in the tool-box to remove the safety hazardous.

Based on different rendering software and display technology, VR systems can provide various levels of immersion (Bowman and McMahan, 2007). The level of immersion refers to the objective level of sensory fidelity, which might play an essential role in helping students develop spatiotemporal awareness. Some applications apply computer screens as display hardware and allow students intact with the virtual construction sites by mouse clicks (Shen et al., 2012; Zhang et al., 2017). This display technology is easily accessible to a large population of students, and it does not require them to spend extra time and effort on learning how to use it; yet the level of immersion provided by such VR systems is relatively limited. On the other hand, Maghool (2018) and Lucas (2018) applied head-mounted displays for students to wear during the VFTs, and students can use the controller to interact with the 3D objects in the VR environment. These systems provide students with a higher level of immersion, which significantly help students develop spatiotemporal awareness (Lucas, 2018).

The advantage of virtual reality technology is that it enables educators to have full control on creating specific activities and tasks for particular learning outcomes and provide an active, experiential learning experience for students where they can freely explore anywhere on the construction sites. However, limitations of applying VR are also notable: no matter what level of immersion can VR systems provide, the virtual simulation using 3D models, provide limited sense-of-realism and level of details. The interactable models in VR systems require a significant amount of time and computational power to generate, and the final product can hardly include every physical detail of real components. This lack of true-to-world representation of reality might prevent students from fully understanding the complexity of a real construction site and its realistic spatiotemporal context.

LEARNING ASSESSMENT TECHNIQUES AND OUTCOMES

As an innovative and promising educational tool, it is essential to understand how effective VFT is when it is integrated within actual courses. In order to gain a better understanding of how previous VFTs were assessed and what effect they had on students' learning, this study analyzed the assessment techniques and outcomes of included applications.

All previous VFT applications used subjective assessment techniques, including questionnaires and interviews, to understand students' feedbacks in such learning experience. This type of technique directly asked students how VFT can help learning and the quality of VFT as a learning tool. Furthermore, the students were able to provide feedback on both advantages and disadvantages of virtual tours compared to typical on-site field trips. It was noticed that there were quantitative measurements conducted in some studies, yet the scope of measurement was beyond the learning contents covered by VFT. For example, Zhang et al. (2017) designed questions and tasks to assess knowledge obtained from both the textbook and the VFT. Therefore, these measurements were not considered as direct assessment for VTFs applications. The outcomes of the subjective assessment outcomes found in these publications were mostly positive. As an educational tool, the virtual trip can provide informative and relevant materials, and students indicated that the amount of information perceived from the virtual trips is higher than the information offered in a traditional classroom setting (Wilkins and Barrett, 2000; Maghool, 2018). Students have recognized several advantages of VFTs on enhancing the learning experience, including (1) helping students understand the materials better than on paper, (2) developing spatiotemporal awareness (Lucas, 2018; Quinn et al., 2019). With all these advantages, students considered VFTs as a valuable tool in the future of construction management education (Jaselskis et al., 2010).

CONCLUSION

This study reviewed and analyzed applications of VFTs in the construction domain focusing on (1) subject areas of construction curriculum that employ VFTs; (2) technologies employed to create the VFT; (3) learning assessment techniques in the virtual trips. VFT has been mostly integrated with courses in fundamental and introductory level, without a specific focus on certain construction learning outcomes. Without focusing on a specific learning outcome, students may find it distracting during the field trip since many tasks are happening at the same time in a complex environment of a construction site. This issue might negatively affect student learning during the VFT. The technology to develop VFTs can be categorized into captured-reality and virtual reality technology. Captured-reality provided an accurate representation of real-word spatiotemporal context while virtual reality delivered a fully explorable simulation of a construction site. Additionally, it is worth noting that all previous researches used subjective assessment techniques. This may be due to the general learning outcomes of such VFTs. By narrowing down the scope of learning outcomes of VFTs, objective and quantitative assessment techniques could also be implemented within the VFTs. Furthermore, educators should also consider taking advantage of rich features that VR provide to evaluate VFTs within the virtual environment. For example, questions can be embedded in given 3D scenarios in the virtual environment. As an example, Zhang et al. (2017) created safety hazard identification feature in their VR-powered VFT, which enabled students to actively explore the virtual site, identify different hazards, and remove them properly. There are great potentials in using VFT in the construction curriculum as they help overcome spatiotemporal constraints in real-world, and meanwhile expose students to a complex environment and help them understand the dynamic construction processes on site.

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