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Influence of Pedagogical Agent Deictic Gestures on Construction Management Students Learning within a 360-Degree Virtual Field Trip

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Field trips are widely recognized as an essential educational component to connect classrooms with the real world. When students don't have access to real field trips, virtual ones have been developed by educators and researchers. Pedagogical agents have been applied to serve as a tour guide and educational tool that facilitate students learning in a virtual learning environment. Such agents are computer software generated and controlled entities that replicate or emulate humans. Previous studies have found that adding anthropomorphic traits to pedagogical agents in learning environments has significantly improved students' learning experience; however, this area has yet been explored in the context of a virtual construction field trip. In this study, a virtual field trip to a complex mechanical room was developed using 360-degree panoramas and a pedagogical agent was employed to lead the tour. This study focuses on one single anthropomorphic trait - deictic gestures, which are pointing gestures used to refer to specific objects – and explores how such trait affects students' quantitative learning outcomes and feedbacks on four aspects of the agent, including facilitating learning, credibility, human-like, and engaging. It was found that deictic gestures can improve students' learning performance and attitudes on multiple aspects of the agent.

Key Words: Construction Education, Virtual Field Trip, Pedagogical Agent, Anthropomorphic Traits, Deictic Gesture

Introduction

A construction field trip is an interactive and essential component of construction education that connects classrooms with the real world, where students are traditionally transported to real construction jobsites to meet personnel and observe the dynamic construction working procedures (Eiris Pereira & Gheisari, 2017; Murray & Tennant, 2016). The field trip has been actively implemented within multiple construction curriculums such as mechanical, electrical, and plumbing system, facility operation, and maintenance, and construction materials (Eiris Pereira & Gheisari, 2017). Field trips help students build a spatiotemporal awareness and provide students opportunities to obtain technical and practical knowledge onsite to reinforce the core concepts they learn in class (Arslan, 2004; Eiris Pereira & Gheisari, 2019; Mills, Ashford, & McLaughlin, 2006). However, there

are a great amount of logistic and spatiotemporal challenges associated with the implementation of field trips, such as safety concerns, travel expenses, time conflict with other classes, large class sizes, and not being able to see or hear in a crowed or noisy environment (Wen & Gheisari, 2020). The COVID-19 pandemic that has been lasted for two years further prevents educators to plan and implement such trips, resulting in fewer opportunities for students to observe complex and dynamic construction activities in a real-world setting.

To overcome barriers of traditional field trips, researchers and educators have explored virtual learning environments that support an experience of observing the physical conditions of a construction project via the Internet or other technologies (i.e., virtual field trip applications) and such environments can be assessed anytime anywhere by students (Eiris & Gheisari, 2017; Finch & Wing, 1996; Jaselskis et al., 2011; Wen & Gheisari, 2020). For instance, Eiris, Wen, and Gheisari (2020) developed a masonry materials' field trip using 360-degree panoramas, and students perceived this platform as easy to use and highly realistic. Among these virtual field trip applications, pedagogical agents have been applied to serve as a tour guide and educational tool that facilitate students learning in a virtual learning environment (Eiris et al., 2020; Eiris, Wen, & Gheisari, 2021a, 2021b). Such agents are computer software-generated and controlled entities that replicate or emulate humans (Eiris & Gheisari, 2017). Anthropomorphism is defined as the attribution of human traits, emotions, or intentions to non-human entities. Previous studies have found that adding anthropomorphic traits to pedagogical agents in learning environments has significantly improved students' learning experience (Lester et al., 1997; Lester, Zettlemoyer, Grégoire, & Bares, 1999; Mayer, 2014; Mayer & DaPra, 2012). However, this area has yet been explored in the context of a virtual construction field trip. This study focused on one single anthropomorphic trait: deictic gesture. Deictic gestures are pointing gestures used to refer to specific objects. In this study, deictic gestures were incorporated into the pedagogical agent to refer objects in the 360-degree learning environment. A virtual field trip, namely *iVisit*, to a complex mechanical room was developed using 360-degree panoramas and a pedagogical agent was employed to lead the tour. This study contributes to the body of knowledge by understanding how deictic gestures affect students' quantitative learning outcomes and feedbacks on four aspects of the pedagogical agent, including facilitating learning, credibility, human-like, and engaging.

Relevant Studies

Pedagogical agents are lifelike characters presented on a computer screen that guide users through multimedia learning environments and they have been widely used in such environments (Seel, 2011). Previous research shows that the inclusion of pedagogical agents in the learning environment improves students' learning and overall learning experience (Lester et al., 1997, 1999). For example, a study conducted by Lester et al. (1999) showed that merely the presence of lifelike character in the learning environment had a positive effect on students learning experience. Due to the positive effect of the pedagogical agent in the learning environment, there has been significant research in designing pedagogical agents to bring the most out of pedagogical agents to assist learning. Previous research shows that the addition of anthropomorphic traits to pedagogical agents can significantly improve learning in students. For example, a study conducted by Lester et al. (1997) involved a pedagogical agent with five different levels of expressiveness with respect to hand gestures and speech. The study found that students who learned from fully expressive agents performed significantly better than students who learned from other agents. Another study showed that the addition of anthropomorphic attributes like facial expressions and deictic gestures also significantly improved learning in students (A. L. Baylor & Kim, 2009). Although anthropomorphic traits, in general, improve learning, there is

evidence in previous research suggesting that certain anthropomorphic traits influence more in specific learning topics (A. L. Baylor & Kim, 2009; Bergmann & Macedonia, 2013). For example, iconic gestures were found to be positively affecting learning new foreign languages (Bergmann & Macedonia, 2013), deictic gestures were found to be positively affecting learning in procedural modules, and facial expressions were found to be positively affecting learning in attitudinal modules (A. L. Baylor & Kim, 2009). Therefore, it is necessary to find out the effects of anthropomorphic traits in different learning topics. This study investigates the effects of gestures (specifically deictic gestures) in the field of construction management where a pedagogical agent leads a virtual field trip.

Methodology

In this section, the platform development for the virtual field trip (iVisit) and the experimental design are discussed. To develop the iVisit platform, a 360-degree virtual learning environment would be created to provide background contexts for a complex mechanical room. Meanwhile, pedagogical agents were models, and deictic gestures were carefully designed for iVisit contents. Then, a between-subject study was conducted, and two experimental conditions were applied. Condition 1 employed a pedagogical agent with no deictic gesture while Condition 2 employed a pedagogical agent with deictic gestures. The 360-degree virtual learning environment of a mechanical room and the learning contents that were covered during the field trip was exactly the same in both conditions. The study measures would also be introduced in this section.

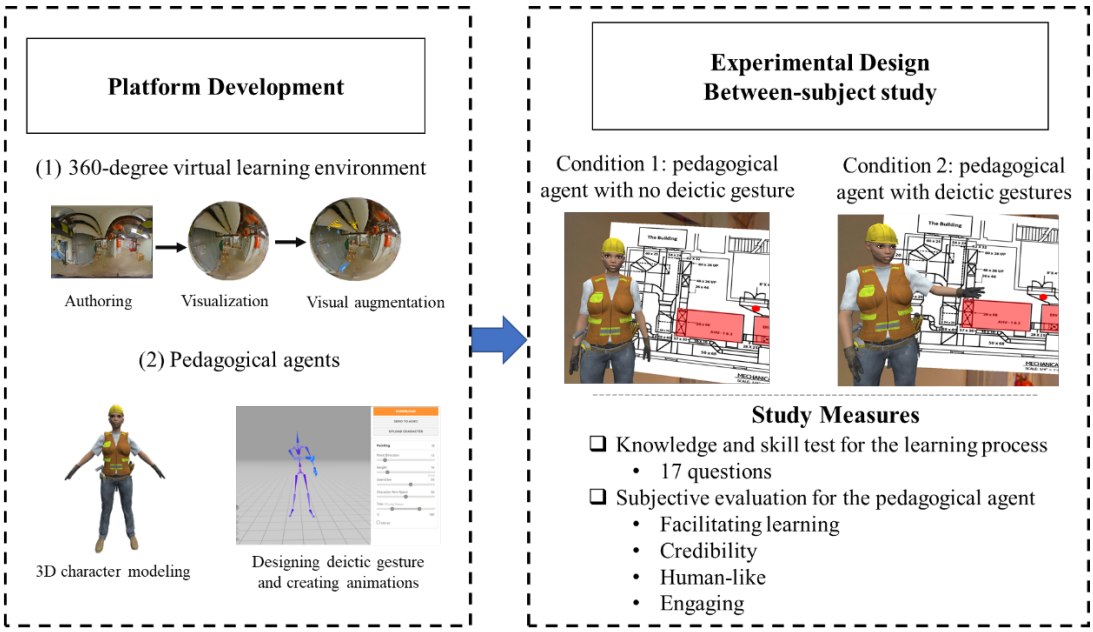

Figure 1. Research Methodology

Platform Development

In this process, the development of the iVisit platform is introduced: the creation of component (1) 360-degree virtual learning environment, and generation of component (2) pedagogical agents (Figure

1). For component (1), 360-degree panoramic images of selected locations in the mechanical room were captured using the 360-degree cameras and authored into equirectangular scenes using computer software. Then, game engines (i.e., Unity) that support 3D graphics were used to render the 360-degree panoramic environment. The equirectangular scenes imported to the game engine were projected into spherical visualization of the mechanical room, where the user's perspective is in the middle of the sphere. Finally, visual augmentations were superimposed over the 360-degree environment to provide users with more detailed information or visual highlights for designated locations or equipment in the mechanical room.

The pedagogical agent used for purpose of this study was developed using Daz3D. The Pedagogical agent was designed whose clothing matches with a construction worker's attire, which matched the context of the construction background and lead to persuasion and credibility (Chaiken, 1979; Eiris et al., 2020, 2021a). A female pedagogical agent was chosen because previous research says that female instructors motivated learners, increased interest in engineering fields, and self-efficacy in students (Plant, Baylor, Doerr, & Rosenberg-Kima, 2009). The pedagogical agent model was then exported to Unity as an FBX file. Animations for the pedagogical agent were imported from Mixamo, which provides a wide of animation for humanoid animated characters. For this study, we used deictic gestures in which the direction of pointing can be adjusted to the required direction. To point to different objects in the 360-degree environment, deictic gestures were configured based on the direction requirements in Mixamo. The resulting animations were imported to Unity and configured to humanoid animation. The humanoid animation was then applied to the pedagogical agent to refer to different objects in the 360-degree environment.

Experimental Design

Study Procedure

To understand the effects of deictic gestures on students' learning in the 360-degree environment, a between-subjects study was conducted with two conditions: agent with no deictic gesture (i.e., No-Gesture group) and agent with gestures (i.e., With-Gesture group). For the study, we recruited participants from two undergraduate classes in construction management. Students were provided extra credits as compensation to participate in the study (IRB202100669).
The study was conducted using Qualtrics. During the study, participants went through four stages, informed consent, pre-survey, iVisit interaction, and post-survey. After the consent form, participants were assigned to one of the two conditions evenly. After finishing the pre-survey, students were asked to download the iVisit platform. iVisit platform was pre-uploaded to the cloud, and a shareable link was generated and embedded in the Qualtrics for students to download the iVisit platform. iVisit contained two sessions: a learning session and an assessment session. The learning session included three scenes that explained the working of the heating, ventilation, and air conditioning system in a building. The assessment session consists of 17 questions based on the contents students studied in the learning session. After the iVisit experience, students were asked to complete a post-survey to subjectively evaluate the pedagogical agent in iVisit.

Study Measures

To evaluate the impact of the deictic gestures on students' learning, 17 knowledge and skill questions were embedded in iVisit to quantitatively evaluate students learning outcomes. These 17 questions were specifically developed based on the learning contents that were covered in the mechanical room

trip. Some questions were location-sensitive (i.e., asking students to identify certain locations) to make sure students understood not only what the equipment or device was and how did it work, but also understood the spatial arrangement in the mechanical room. These questions were validated by the class instructor as well as the expert in the associated area. Furthermore, this study used an Agent Persona Instrument (API) survey questionnaire for students to evaluate the persona of the pedagogical agent. API has been used in multiple studies to understand the effectiveness of the pedagogical agent in learning considering four aspects: facilitating learning, credibility, human-like, and engaging (A. Baylor & Ryu, 2003). API considers two important constructs, (1) Informational usefulness and (2) Affective Interaction. Facilitating learning and credibility reflects on the Informational Usefulness construct, while human-like and Engaging reflect on the Affective Interaction construct of the pedagogical agent. The four aspects would be assessed by multiple statements on a 5-point Likert scale where one indicates strongly disagree and five means strongly agree. The responses for each aspect were aggregated and normalized from a 0 to 100 range. The detailed descriptions for each aspect were as follows:

- Facilitating learning aspect refers to how the agent facilitates learning and reflection. Higher scores indicated students are more likely to positively rate the agent as a learning facilitator.
- The credibility aspect refers to the value of the advice or instruction from the agent. A higher score indicated students' higher level of recognition of the agent's credibility.
- The human-like aspect refers to the naturalness of the agent's nonverbal communication with respect to personality and emotional expression. A higher score indicated students' higher level of recognition of the agent's human-like feeling.
- The engaging aspect refers to the level of motivation provided by the agent. A higher score indicated the pedagogical agent supported a higher level of engagement.

Data Collection and Analysis

Twenty-six students were participating in the experiment and were randomly assigned to No-Gesture and With-Gesture groups. Both groups had thirteen participants where ten of them were male and three of them were female students. The average ages for the two groups were very similar (No-Gesture: 21 vs With-Gesture: 20). Overall, participants in the two conditions shared very similar demographic backgrounds; besides, as they were recruited from the same classes, their academic backgrounds were also considered similar. An analysis was performed using descriptive statistics. It was found that students in the With-Gesture group gained a higher score (Mean: 61.09%; STD: 3.78%) for the knowledge and skill test than students in the No-Gesture group (Mean: 56.33%; STD: 5.64%). Overall, students in the With-Gesture group rated the pedagogical agent more positively from all aspects (facilitating learning, credibility, and human-like) except the engaging aspect (Table 1). Additionally, the independent samples t-tests were performed for four measures; however, there was no significant difference detected (Table 1).

Table 1: Results of the Descriptive Analysis and Independent Samples T-Tests

Measure	Group	Mean	SD	Independent Samples T-Test	
				W	p
Facilitating Learning	No-Gesture	63.93%	3.72%	80.50	0.313
	With-Gesture	66.15%	4.72%		
Credibility	No-Gesture	75.90%	5.04%	76.00	0.237
	With-Gesture	81.54%	3.47%		
Human-like	No-Gesture	37.80%	5.41%	77.00	0.254

	With-Gesture	39.08%	3.36%		
Engaging	No-Gesture	57.85%	3.50%	98.50	0.652
	With-Gesture	54.46%	5.61%		

Discussion and Conclusion

Generally speaking, students in both conditions presented somewhat positive attitudes on the credibility aspect of the pedagogical agent, as *'(the) agent was smart and credible, I didn't doubt any of the words or knowledge it said'.* Students also presented slightly positive attitudes on facilitating learning and engaging aspects of the agent. Nevertheless, a somewhat negative attitude on the human-like aspect of the pedagogical agent was observed in both conditions. Noticeably, the majority of students (21 out of 26) commented on the monotone and robotic voice and suggested applying a real human's voice for the agent may help with the engaging and human-like aspect of the agent. The results of the independent samples t-test suggest that deictic gestures did not influence students' perception of the pedagogical agent. Given the significant amount of students who provided negative comments regarding the voice, it is potential that the robotic voice dramatically distracted students; therefore the actual conditions (with or without deictic gestures) may not be allocated with proper attention from students. This aligned with students comment *'The voice was very monotone and sometimes it was hard to pay attention.'*

Therefore, in the future applications of the pedagogical agents in the learning environment, specific significance should be attached to the application of the natural or real human voices. This study also found pedagogical agents implementing deictic gestures can improve students' learning performance and result in higher knowledge and skill scores. However, such findings are only limited to the current participants and need careful considerations for generalization. Moreover, future researchers and educators need to carefully consider and balance the benefit of the deictic gestures and their effort investment in the implementation of the gesture. In the future, more participants will be recruited in the construction management classes in the following semesters, and their demographics (such as age, gender, year in school) would be also investigated to find if any of the demographics affect the research outcomes. Statistical analysis will be conducted to detect the correlations between students' demographics, learning performance, and the pedagogical agent's informational usefulness and affective interaction in the virtual learning environment.

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