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Teaching training in a mixed-reality integrated learning environment

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ABSTRACT

In this mixed-method study, we examined the design and potential impact of a mixed-reality integrated learning environment (MILE) in providing the simulated and immersive teaching practice for university teaching assistants. A virtual-reality-based learning platform integrating a Kinect-enabled sensorimotor interface was developed and used by twenty three university teaching assistants. Qualitative and quantitative data on the participants' participation behaviors, engagement, and perceptions were collected via video/screen recording, interview, surveys on teaching self-efficacy and sense of presence, and eye tracking. Results indicated that the MILE reinforced sense of presence and supported the performance of an ample range of virtual teaching tasks/actions with avatar-embodied live gesturing. The environmental fidelity in the mixed-reality learning spaces, the design and arrangement of virtual agents and avatars, and the affordance of embodied gesturing and walking are salient MILE design features that affected participants' sense of presence and their virtual teaching performance.
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1. Introduction

The recent development of computer hardware and software has made it feasible to incorporate Internet-based, 3D virtual reality (VR) in innovative applications of teaching, learning, and training (Abulrub, Attridge, & Williams, 2011; Gregory et al., 2013; Jou & Wang, 2013). Virtual reality (VR) or virtual world is a computer-generated 3D representation of real-life environments. A user can autonomously navigate around a VR (in the form of *avatars*) and interact with simulated objects and other avatars in real time at the same pace one would experience events in the real world (Mitchell, Parsons, & Leonard, 2007). In comparison with other computerized programs, virtual reality supports realistic, immersive simulation to enable the transfer of skills between taught and real contexts, and provides a multi-user, embodied, and interactive space for real time active learning (Cheng & Wang, 2011). It is speculated that VR can act as a promising tool for training skill application and complex problem solving that requires weighing multiple variables and situational decision making (Bertram, Moskaliuk, & Cress, 2015; Cheng & Wang, 2011; Dede, 2005, 2009).

The emerging 3D body sensory technology, such as Microsoft Kinect, can be used as an intuitive interface to create a naturalistic, augmented interaction between users and a VR-based simulation, thus merging real and virtual worlds to support the mixed reality (Ohta & Tamura, 2014). A Kinect captures a user's body gestures and replicates them in a computer application, which offers new ways of human-computer interaction in educational settings. In a Kinect-enabled, mixed-reality environment, a user can use physical body movements to interact with the virtual characters and objects in the virtual reality. Kinect-based applications in a VR setting may help to enhance the sense of presence and immersion, and facilitate embodied and situated cognition of learners.

The use of a mixed-reality integrated learning environment (MILE) is just emerging (Hayes, Straub, Dieker, Hughes, & Hynes, 2013; Liarokapis & Anderson, 2010; Staub, Dieker, Hynes, & Hughes, 2014), and is in need of empirical research on its design, implementation, and educational effectiveness. In this study, we examined the design and application of a mixed-reality integrated learning environment – a virtual reality learning platform that integrates a Kinect-enabled sensorimotor interface – in the setting of teaching training for university teaching assistants. Teaching is a complex problem solving task that requires contextualized and adaptive implementation of content representation and (both verbal and embodied) interpersonal interaction. Learning to teach is a challenging and important area of inquiry for educational

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practice and research (Quintana & Fernández, 2015). Examining the implementation of MILE for teaching training will help to inform the role of this emerging platform in providing embodied, immersive interactions for learning a complex task, and to test its implementation feasibility via the lens of future teachers. Specifically, this exploratory study aimed to address two research questions: (1) What is the effectiveness of the mixed-reality integrated learning environment for teaching training? (2) What features of this learning environment influence participants' perceptions and teaching-training experiences?

2. Theoretical framework

2.1. Sense of presence and immersion in a virtual learning environment

Sense of presence refers to "a state of consciousness" and the psychological sense of being in the virtual place (Barfield & Hendrix, 1995; Heeter, 1992; Lee, 2004; Slater & Wilbur, 1997, p. 1; Witmer, Jerome, & Singer, 2005). Previous studies reported that sense of presence reduces the social distance between learners, and enhances skills acquisition and knowledge transfer by allowing multiple perspectives and situated performance (Dede, 2009; Mantovani & Castelnuovo, 2003; Palloff & Pratt, 1999; Slater & Wilbur, 1997). It was found that sense of presence in virtual learning environments foster learners' motivation, learning engagement, and potentially learning outcomes, by enabling focused and naturalistic interactions with learning materials and activities (Mikropoulos, 2006; Persky et al., 2009; Selverian & Hwang, 2003).

A design construct closely related to sense of presence is immersion – the extent of "the subjective impression that one is participating in a comprehensive, realistic experience" and "the semi-voluntary experience of being transported into an alternate context for an extended duration" (Buchanan, 2006, p. 10; Dede, 2005, p. 10). Prior research suggested that the higher level of immersion is associated with the higher level of presence (Bystrom, Barfield, & Hendrix, 1999; Faiola, Newlon, Pfaff, & Smyslova, 2013; Slater & Wilbur, 1997). Experience of immersion can be created via the sensory and environmental fidelity in the three-dimensional virtual space, engagement with the virtual actions, and emotional experience activated by the archetypical scenarios in the virtual space (Dede, 2009).

The recent development of computer hardware and software has made it feasible to incorporate Internet-based, 3D virtual reality (VR) to create an immersive learning environment (Abulrub et al., 2011; Gregory et al., 2013). In fact, VR has been implemented as a promising learning platform to support a variety of education activities in both formal and informal learning settings (Hew & Cheung, 2010; Jou & Wang, 2013). In a qualitative, observatory study, Quintana and Fernández (2015) reported that immersive virtual reality can provide a virtual space to simulate teaching challenges and hence act as a pedagogical tool for the collaborative teaching training program. In comparison with other computerized programs, VR is characterized with representational fidelity and learner interaction, supports a psychological sense of presence and an immersive practice to facilitate experiential learning, and provides a multi-user space for embodied interactions (Dalgarno & Lee, 2010). Previous studies suggested that the immersive VR learning environment also fosters situated learning through simulating authentic contexts and providing contextualized learning activities (Bailenson et al., 2008; Barab, Sadler, Heiselt, Hickey, & Zuiker, 2007; Ketelhut, Dede, Clarke, Nelson, & Bowman, 2007), thus improving performance transfer from the learning context to the real-world setting (Bossard, Kermarrec, Buche, & Tisseau, 2008; Park et al., 2007). The unique affordances of an immersive VR learning environment include: (a) virtual agents and avatars that act as personalized and interactive learning partners that cannot be easily arranged in a physical setting, (b) the open-endedness in creating and customizing the 3D VR environment that enables the provision of multiple perspectives and scenarios for the targeted concepts and skills, and (c) the potential to transform sensory representations to enhance virtual learning actions (Bailenson et al., 2008; Dede, 2009).

2.2. Embodied and situated cognition

Situated and embodied cognition theories hold that cognition is not abstract or centralized but a situated activity that takes place in active and continuous interactions with the environment, vastly via perceptual and motor activities (Brown, Collins, & Duguid, 1989). Motor functions are traditionally considered only peripheral input and output devices for the 'central' cognitive processes. But the evolving perspective of embodied cognition argues that cognitive processes are deeply rooted and should be understood in the context of the body's interactions with the environment (Anderson, 2003; Shapiro, 2010; Wilson, 2002). Sensorimotor processing, thus, becomes a meaningful context and a necessary part of cognitive processing. Another perspective of embodied and situated cognition is that cognitive processing can be off-loaded onto the external environment, via either real-time, task-relevant actions or off-line, mental simulations of sensorimotor experiences. The emergence and development of 3D motion sensing technology, such as Microsoft Kinect, has provided a valuable and exciting avenue for implementing and examining the propositions of the embodied and situated cognition when designing an active and meaningful learning environment.

Schubert, Friedmann, and Regenbrecht (1999) framed presence as the consequence of embodied cognition – presence emerges when bodily actions in a virtual environment are mentally represented and the virtual environment is actively interpreted. The central interactions with the virtual environment that foster embodied presence are the representation of navigation and movement of one's own body as an action in the virtual world (Bailenson et al., 2008; Schubert et al., 1999). Prior research on learning in virtual learning environment typically examined embodied agents (driven by computer algorithms) as opposed to avatars (driven by humans in real time). It is due to the lack of readily available commercial technology that allows the creation of digital avatars who track and render users' gestures in a collaborative virtual learning environment (Bailenson et al., 2008). Hence it is necessary to conduct an empirical investigation to explore the implications of the behavioral realism (i.e., embodied presence) of the avatar enabled by the body sensory technologies in the VR environment for learners' sense of presence and engagement.

2.3. Mixed-reality integrated teaching training for graduate teaching assistants

Teaching is a complex problem-solving task that requires weighing many variables and adaptively implementing principles of instruction, communication, and content representation in a highly situated context (Dick, Carey, & Carey, 2011). Rather than mechanically executing a preset sequence of instructional events, teaching involves dynamic and complex interpersonal interaction skills. Graduate teaching assistants (GTAs) participate extensively in class, laboratory, and recitation teaching in higher education. Teaching training for GTAs, then, is critical for supporting curriculum reforms, bolstering college teaching and learning, and training future faculty members (Marincovich, Prostko, & Stout, 1998; Park, 2004; Pentecost, Langdon, Asirvatham, Robus, & Parson, 2012). In spite of the important role of GTAs in higher education, few receive formal training in teaching (DeChenne, Enochs, & Needham, 2012; Meyers, Lansu, Hundal, Lekkos, & Prieto, 2007; Prieto & Scheel, 2008).

The research on GTA training is limited and fragmentary (DeChenne et al., 2012). Innovative efforts to bridge GTA teaching training and research gaps are essential to promoting quality higher education, and to preparing highly-qualified future faculty in different academic disciplines. Feezel and Myers (1997) found that GTAs experience eight interrelated types of communication concern that affect these skills: self, task, impact, role conflict, teaching, area knowledge, procedural knowledge, and time management. International teaching assistants face additional challenges because of linguistic differences and cultural diversity and sensitivity. However, prevalent formal training programs for GTAs depict mainly administrative orientations and introductory presentations on pedagogy (Pentecost et al., 2012). The opportunity for problem- or simulation-based training in instruction for GTAs is scarce.

The recent development of 3D body sensory technology, such as Microsoft Kinect, can be used as an intuitive interface to create a naturalistic, augmented interaction between users and a VR-based simulation. Specifically, in a Kinect-integrated VR environment, a GTA can use physical body movements to control an instructor-avatar to perform augmented and active teaching practice in a simulated class, or he/she can be embodied as a student in the class to observe, critique, and learn from the teaching performance of another GTA.

The use of mixed reality for simulated teaching and training is just emerging, but there is preliminary evidence of its instructional effectiveness (Hayes, Hardin, & Hughes, 2013; Hayes, Straub et al., 2013; Liarokapis & Anderson, 2010). For example, Hayes, Hardin et al. (2013), Hayes, Straub et al. (2013) examined the user experience of a 3D mixed-reality integrated classroom (called TeachLivE ™, which uses a group of five simulated/NPC students) that is used to facilitate virtual rehearsal of lecturing and classroom management by K–12 teachers. The descriptive case evidence suggests that sense of presence and immersion in this mixed-reality integrated classroom promotes engagement and the targeted teaching practice. It is warranted to further examine the design and potential effectiveness of the mixed-reality integrated teaching training for GTAs in the higher education setting.

3. Method

Due to the lack of systematic investigation, and hence, the lack of design foundation and conceptual distinctions of the mixed reality integrated learning environments (MILE) for the teaching training with GTAs, this study was structured using the exploratory research framework. This mixed-method case study (Yin, 2013) aimed to examine a MILE in its naturalistic implementation context to delineate salient design factors of the MILE and the potential explanatory relationship between design features and participants' learning processes and perceptions. Data were collected via both qualitative and quantitative methods on the design specifications and potential effectiveness of the VR-based, Kinect-integrated learning environment.

3.1. Participants and mixed-reality integrated learning environment

Twenty three university teaching assistants were recruited from the disciplines of education ($n = 10$), engineering ($n = 5$), business ($n = 2$), and arts and science ($n = 6$) in a land-grant university in United States. All these participants were international graduate students from 6 different countries, including 12 females and 11 males. Out of the 23 participants, 7 had less than one-year teaching experience, 6 had both online and face-to-face teaching experience, and all were non-native English speakers.

Delivered via OpenSimulator (an open-source VR platform), a virtual class simulation was designed to simulate the daily classroom setting at the university. Each participant was requested to practice teaching in this virtual class, including lecturing, mentoring, and classroom management. The simulated audience in the virtual class were a mixture of non-player characters (NPCs) controlled by the artificial intelligent (AI) script and student avatars played by peer trainees. Using Kinect and a middleware that connected and interfaced Kinect with the Opensimulator platform, this 3D virtual class (see Fig. 1) enabled participants to project and embody their real-time body movements and gestures onto their avatars in the virtual world.

3.2. Data collection

3.2.1. Procedure

All participants were surveyed on their teaching self-efficacy, demographics, academic background, and teaching experience before the intervention. They were then provided a pre-study orientation on the mixed-reality integrated learning environment (MILE), and requested to participate in two one-hour MILE teaching-training sessions.

In one session, each participant was requested to teach a self-chosen, domain-specific content topic to a virtual class of students. In the other session, the participant would sit in the virtual class, act as a student along with other avatars and agents, and interact with the virtual instructor played by another peer participant. It was speculated that acting as a student and observing how peers teach a novel topic would award the participant an opportunity to experience, observe, and reflect on varied teaching actions and strategies, and potentially facilitate an interactive learning experience by having participants challenging and critiquing each other during the virtual class. The sequence of participating in the two sessions was selected by each participant and randomized across all. Right after the first session, every participant received a survey on the perceived sense of presence in the virtual class and a second survey on their teaching self-efficacy. At the end of the second session, participants were surveyed again on their sense of presence and teaching self-efficacy.

Every MILE intervention session was screen and video recorded; the recordings captured both online and offline behaviors of participants when they interacted with the VR simulation via the Kinect interface. Every participant received a 30-min, video-stimulated, semi-structured recall interview at the end of each intervention session. The interview focused on exploring participants' perceptions and experiences of the MILE. Six randomly selected individual participants were also eye-tracked using the kit of *ASL Mobile Eye Tracking* during the MILE-based teaching process. Eye-tracking data would contribute supplementary data, in addition to the observed behaviors of participation, to provide information about the level of engagement and hence sense of immersion exhibited by the program participants.

3.2.2. Instruments

Pre-, during-, and post-intervention teaching self-efficacy were measured via a customized version of the Teaching Self Efficacy Scale (Tschannen-Moran & Woolfolk Hoy, 2001; 22 items, 9-point scale, $a = 0.89$ in this study). Two individual items in the original scale questioned on the teaching practice that was not applicable in the current study (e.g., “How much can you assist families in helping their children do well in school?”), and hence were

Fig. 1. A screen capture.

removed. In certain survey items, the phrase of "in school" in the original scale was customized to "in class" to reflect the targeted teaching setting in this study. A customized version of the presence Questionnaire (Witmer et al., 2005; 24 items, 7-point scale, a = 0.97 in this study) was used to measure participants' sense of presence in the VR-based, Kinect-integrated learning environment. Two items that questioned on the touchable interface in the original questionnaire (e.g., "How well could you actively survey or search the virtual environment using touch") were customized and replaced by two items measuring the sense of presence with the virtual gesturing (e.g., "How well could you communicate using gestures in the virtual environment?"). Both scales' construct validity has been validated by infield, scale development studies (Tschannen-Moran & Woolfolk Hoy, 2001; Witmer et al., 2005). The scales were also reviewed and validated by a panel of multimedia and instructional design experts, comprising faculty members and doctoral students in the field of educational psychology and instructional design, in this current study.

3.3. Data analysis

Descriptive statistics and paired t-tests were conducted with the survey results to examine whether the sense of presence was supported and sustained in the VR-based, Kinect-integrated learning environment, and to investigate the potential changes in participants' teaching self-efficacy. We conducted a behavior analysis with the recorded participants' performance in the intervention sessions. Systematically, we coded the recorded virtual-participation behaviors per 30 seconds and categorized the attributes, contexts, and frequency of salient actions to explore the nature of the MILE-based lecturing, gesturing, interaction, and classroom management. We then performed a qualitative thematic analysis with the interview data, focusing on learners' perceptions of the MILE for the teaching practice. We triangulated the survey, behavioral analysis, and thematic analysis findings to gather the descriptive evidence on the effects of the MILE and develop propositions on the association between its design features and learning effectiveness. Eye-tracking data were analyzed to identify patterns of engagement and potential evidence of sense of presence of participants during the MILE-based teaching training.

4. Results

4.1. Sense of presence and immersion

The paired *t*-test comparing the sense-of-presence survey response at the end of the first intervention session ($M_1 = 108.1$ out of a total of 168, $SD_1 = 18.4$) with that at the end of the second session ($M_2 = 105.1$, $SD_2 = 22.6$) did not indicate a statistically significant difference, $t(22) = 0.73$, $p = 0.47$. Both had a mean value that was higher than 60% of the maximum scale score. This result suggested that the sense of presence was fostered and sustained during MILE-based teaching training and there was no differential effect of acting as a teacher or a student in the virtual world on the sense of presence. During the interview when participants were asked to rate the degree of immersion in the MILE, only 2 out of all 23 participants gave an estimate lower than 60%. Specifically, participants' responses to the survey items on live gesturing in VR indicated a general endorsement of Kinect-based embodied presence, $M = 8.4$ (60% out of 14), $SD = 3.4$.

Via the behavior analysis of participants' actions and reactions in MILE sessions, we further explored the affordance of the non-player characters (NPCs), Kinect-enabled virtual gesturing, and the VR-based teaching simulation for fostering learner immersion in the MILE. The result indicated that around 56% of the NPC-related participant behaviors portrayed a positive experience of immersion. Particularly, it was found that participants tried to interact with an NPC in the same earnest manner as that with a real student, "Mario (an NPC student), is that your leg on the table? What is that? Put your leg DOWN please!" Yet the low voice volume, occasional out-of-context inquiries (e.g., requesting the extension of assignment deadlines when the instructor was still giving a lecture), and the lack of reciprocal reactions of NPCs (e.g., Mario did not put down the leg as requested) led to the lessening of realism in NPC-initiated interactions. In the current MILE, NPCs in the virtual class delivered mainly pre-timed, pre-set behaviors and utterances; they could not reciprocally interacted with an instructor or a student avatar. Around 43% of participants reported that in the virtual class they gradually recognized that these characters, different from avatars, were actually "non-human." Consequently, it was observed that those participants attended to lecturing more than student interaction or classroom management in the later part of virtual teaching. One of them commented, "I just don't care anymore."

In general, around 78% of observed user interactions evidenced an immersive engagement of participants in the virtual, simulated teaching environment. In the remaining 22% enactments, participants were found to interact with items in their physical environment (e.g., self-brought lecturing handouts) or question the observing researcher about the virtual class simulation. This observation indicated that the environmental distractions were not fully suppressed and the experience of immersion in the MILE might have been interrupted.

All study participants performed a succession of avatar-embodied live gesturing during virtual teaching. More than 90% of gesturing actions portrayed the experience of embodied presence, which comprised beat gestures in conjunction with the rhythm of speech to emphasize certain phrases, pointing gestures (i.e., act of pointing as a way of referring to an object or event), and representational gestures (i.e., gestures used to explain the form or nature of a concept). The remaining 10% of gesturing and body-movement behaviors demonstrated insufficient virtual presence. Particularly, the Kinect equipment captured a fixed physical area. The embodied gesturing would be interrupted when a participant accidentally stepped out of the capturing zone during lecturing.

4.1.1. Engagement with the virtual teaching simulation

The eye-tracking data in this study (Table 1) have captured the dwell time (i.e., the continuous time spent by participants looking at the selected area of interest – the virtual reality display – regardless of how many individual fixations this involved), and the duration and frequency of fixations (i.e., the pause of the eye movement, for more than 100 ms, on the area of interest). The output indicated an average of 765.06 s for the dwell time *on* the AOI (area of interest – the VR display of the virtual class) in comparison with an average of 205.48 s for the dwell time *out of* the AOI, an average of 367.44 s in the fixation time *on* the AOI versus an average of 66.46 s in the fixation time *out of* the AOI, and an average of 1601.83 fixations *on* the AOI versus an average of 366.5 fixations *out of* the AOI. The output suggested that participants portrayed a high level of attention on the AOI – VR-based teaching simulation, implying a high degree of immersion and engagement.

A further analysis of the eye-tracking and video/screen recording data indicated that participants' gazing out of the AOI (the VR display of the virtual class) occurred mainly in the following situations: (1) deliberating in reaction to a challenging student behavior or inquiry, (2) trying to retrieve materials and find help from an offline lecturing aid, (3) being distracted by the unexpected environmental noise (e.g., coughing or sneezing of the observing researcher), (4) pondering before answering a question or continuing the instruction. Among these four situations, the first and last ones were responses and signs of cognitive engagement (e.g., head tilting or lowering as a sign of uncertainty and thinking). The second and third situations were indicative of physical-environment disruptions formed by a conflicting object of attention (e.g., the offline lecturing aids in addition to the virtual ones) and the lack of exclusiveness in the simulated learning space (e.g., the onsite presence of an observing researcher as a diversion from the virtual presence of VR students).

4.2. Teaching self-efficacy

The paired t-tests with the pre, mid, and post-survey results of the teaching self-efficacy did not indicate statistically significant differences in the teaching self-efficacy before, in between, and after the two intervention sessions, t(pre-post) = 1.50, $p = 0.15$; t(pre-mid) = −0.05, $p = 0.96$. A ceiling effect on teaching self-efficacy may have occurred, due to the finding that before the intervention study participants had reported an average of 76% teaching self-efficacy and a median of 17.5-month teaching experience.

There was actually a numerical decline in teaching self-efficacy from the pre-intervention ($M_{pre} = 150.9$ out of a total of 198, $SD_{pre} = 28.3$) and the mid-intervention conditions ($M_{mid} = 151.0$, $SD_{mid} = 29.9$) to the post-intervention condition ($M_{post} = 132.5$, $SD_{post} = 44.9$). An explanation of such a trend, based on the qualitative data, is that the two-hour MILE intervention helped participants develop a better understanding of the challenges in managing a heterogeneous learner group during lecturing and hence increased their awareness of the lack of competence in classroom management. For the VR-based class simulation, we purposefully gathered and replicated a variety of disruptive student scenarios – complaints (e.g., "I don't understand you!" or "This is boring!"), irrelevant questions, non-compliant behaviors (e.g., putting legs onto the table, leaving class to pick up a cell phone), and verbal challenges (e.g, "Do you speak English?"). Embedded as incessant disturbances during one's lecturing in the virtual class, these disruptive student scenarios appeared to challenge most study participants. They unanimously reported the lack of opportunities to experience and practice on those scenarios in their conventional teaching practice. As observed, participants frequently showed disorientation when encountering disruptive students during virtual lecturing. Some participants ignored or reacted heatedly towards students' disruptive behaviors, or appeared defensive with the interruptive, insolent comments made by NPC students. More participants expressed that the experience of handling difficult students were thought-provoking, as one of them explained, "Negative comment is more effective, because I am curious and cautious when getting negative comments." Participants generally expressed discontent with their failure to complete an intended lecture due to the intermittent classroom-managing encounters. Frequent comments were, "It's hard," "I forgot what I

Table 1
Eye-tracking data.

Eye-tracking		Average	Median
Dwell Time	AOI (sec)	765.06	765.06
	Out (sec)	205.48	205.48
Fixation Time	AOI (sec)	367.44	315.1
	Out (sec)	66.46	49.02
Fixation Frequency	AOI	1601.83	1508
	Out	366.5	284
Lecturing Time	Beginning Time (sec)	333.5	182
	Finish (sec)	1505.67	1436
	Duration (sec)	1172.17	1172.17

intended to say," "I was busy looking at the classroom," and "The experience made me see the gap (between the expected and current teaching performance)."

4.3. VR-based teaching practice

During interviewing, 22 out of 23 participants stated that the MILE should be very helpful for training novice teaching assistants. When asked to rate their virtual teaching experience, participants reported an average of 78% degree of satisfaction. The behavior analysis with participants' virtual teaching processes showed a comprehensive portray of the targeted teaching performance by the participants, supporting the affordance of the VR-based, Kinect-integrated learning environment as an alternative platform for active teaching practice. Salient teaching tasks, teaching actions, and componential strategies performed by the participants during virtual teaching sessions, along with performance frequencies congregated across all participants, are outlined in Table 2.

Among the teaching actions performed by the study participants, 66% were for instruction (or lecturing), 19% were for classroom management, and only 15% was contributed to student interaction. Pertinently, more than 80% of participants expressed a teaching belief that focuses on instruction rather than student interaction or management, as highlighted by a participant comment, "The importance is to prepare the lecture, not the classroom." The reduced involvement in interacting with students may also relate to the difficulty of performing reciprocal and dynamic interactions with NPC students and hence a reduced sense of presence with the instructor-student interaction. Among the instructor-student interactions, 66% were contributed to question answering. Notably, participants had managed to verbally and nonverbally connect to individual students (21% of the instructor-student interactions) and greet them (13%), demonstrating social engagement with their virtual students to some extent.

All study participants were able to deliver a comprehensive and multi-step instruction during the virtual teaching sessions (as shown by Fig. 2). Their lecturing performance comprised all major events and actions that are expected for a conventional instruction.

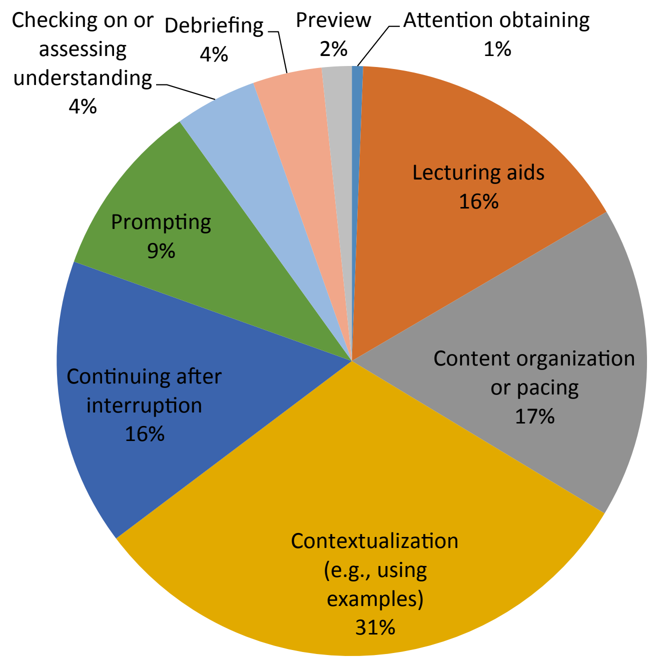

Fig. 2. Distribution of instructional actions and strategies.

Such a finding further affirmed the potential effectiveness of a VR-based, Kinect-integrated learning environment in promoting an authentic teaching rehearsal.

Another observation of the Kinect-integrated learning environment was that study participants were able to naturally convey live gesturing via their avatars during the process of virtual teaching. Among the teaching gestures performed (a total of 663 gestures coded across participants), 29% were *representational* gestures that were used to embody and represent a concept, 18% were *pointing* gestures that aimed to obtain or guide the audience's attention, and 53% were *beating* gestures that were used with the

Table 2
VR-enabled teaching performance.

Task	Action	Strategy	Frequency
Instruction	Pre-teaching preparation	Attention obtaining	6
	Lecturing	Using lecturing aids (virtual PowerPoint slides & offline aids)	156
		Content organization and pacing	167
		Contextualization (e.g., using examples)	304
		Continuing after interruption	154
	Prompting	Verbal and gestural prompts that encourage critical thinking on the information presented	94
	Checking for understanding	Verbal checking on student understanding of the information presented	44
	Debriefing	Summarizing the information presented	37
	Preview	Introduction of the next phase of learning content/activity	16
Student Interaction	Greeting	Verbal and gestural greeting	28
	Connecting to students	Encouraging, joking, intending to placing oneself among students, calling & addressing students	46
	Question-Answering	Answering questions from students	144
Classroom Management	Managing challenging behaviors	Normative – directing or asking students to behave based on common expectations	47
		Coercive – managing students' behaviors based on the power of punishment	34
		Retreatism – letting students act as they want	16
		Remunerative – managing students' behaviors based on the power of rewards	5
		Using humor – using humorous comments or statements during behavioral management	10
		Active: Managing the behavioral issues	30
		Passive: Ignoring the behavioral issues	6
	Handling complaint	Normative – handling complaints based on what is traditionally expected	48
		Coercive – handling complaints based on the power of punishment	9
		Retreatism – for example, apologizing without reasons	11
		Remunerative – handling complaints based on the power of rewards	17
		Using humor – using humorous comments or statements when handling a complaint	6
		Active: Explicitly responding to complaints	39
		Passive: Failing to attend to complaints	4

rhythm of speech. This finding suggested that integrating Kinect in the virtual-reality-based training environment enabled the participants to actively practice both verbal and nonverbal teaching strategies in an integrative manner.

4.4. Salient design features of the MILE

The MILE in this study simulated a conventional teaching environment and a heterogeneous student group with disruptive behaviors/requests. The environmental fidelity of the virtual class, the selection of domain-specific archetypical teaching scenarios/tasks, the arrangement of virtual agents and avatars, and the affordance of Kinect-based embodied gesturing all appeared to influence participants' sense of presence and the externalization of their teaching techniques and beliefs.

4.4.1. Fidelity and design of the mixed-reality learning space

The virtual class, along with the building where it is situated, was designed to fully simulate a conventional classroom in the building of college of education at the sampled university. Participants of education and arts and science majors who were used to such type of classroom all commented the 3D virtual space as “real” or “authentic.” Yet those of other majors criticized that the size, seating arrangement, or interior design of the classroom were “different” from what they experienced or expected, as the following quotes from participants indicated.

“This class was a little small.”

“I don't think the current seating arrangement will work for group activities.”

“I was used to a lab than a teaching station.”

“The colors of the carpet and wall are too dark.”

Those comments indicated the need to customize the classroom design based on varied teaching settings and disciplinary cultures.

A related observation was the importance of selecting and designing domain-specific, archetypical teaching scenarios and tasks. Lecturer-led direct instruction was depicted as the major teaching method in the intervention. Yet multiple participants of science, engineering, and business majors reported that in their academic disciplines, graduate teaching assistants mainly participated in laboratory and recitation teaching that comprised more discussion facilitation or lab-activity mentoring than lecturing.

Unanimously, participants complained about the difficulty of establishing common reference during virtual lecturing. Although the shared media boards in the virtual world enabled media sharing/viewing among the virtual instructor and students, embodied pointing and gazing onto a reference object (e.g., a line within a virtual PowerPoint slide) to achieve joint attention and shared focus during the virtual lecturing was tricky. Particularly, the instructor had to mirror Kinect-enabled pointing or gazing to an object in the physical space onto the corresponding virtual reference in the virtual space (as indicated in Fig. 3). Such an action comprised a fluent and simultaneous execution of multiple steps (e.g., checking on the virtual-reality presentation screen, reading the virtual media board, reading the physical lecturing aid, and estimating the reference point to point to) and was in need of much practice by the teaching trainee. Moreover, certain participants commented on the lack of embodied scripting during virtual lecturing. One explained, “I'd like to use blackboard when I explain something. It might relate to my thinking. I'd like to use some chalk, move my hand, and write something during the lecture.”

Another critical design requirement for integrating the virtual and physical learning spaces to create an immersive MILE is the suppression of environmental distractions from the physical space. In this current study, the MILE was set up in a conventional conference room to better evaluate the implementation of such a learning environment in a low-cost, daily school setting. Researchers stayed in the same room to conduct onsite observation. Thus the exclusiveness of the space could be comprised. Even with the headsets, participants might still be distracted by the presence of the onsite observers. Additionally, some study participants admitted that they did not fully prepare their lectures before the teaching session, and had intermittently looked at the lecturing aids (e.g., papers and slides) in their hands rather than focusing on their virtual students in the class.

4.4.2. Differential roles of virtual agents and avatars

Students in the virtual class comprised both non-player characters (NPCs) controlled by the artificial intelligent (AI) script and avatars played by peer trainees. As observed, NPC agents presented initiative prompts that had stimulated reactive teaching behaviors with emotional experience of participants. “Nervous,” “uncomfortable,” “upset,” and “embarrassed” described emotional reactions of around 65% of participants toward these NPC prompts. The prompts also managed to externalize participants' internal teaching beliefs or preferences. For example, one commented, “I saw him (an NPC student), but I just didn't care. The importance is to prepare the lecture, not the classroom.” Another echoed, “I am kind of shy, so whenever I am dealing with my lecture, I tried to look at my lecture slides.” Correspondingly, participants were found to be either active or passive in managing student behaviors, portraying different student-management actions that were normative, coercive, retreating, or remunerative (as described in Table 2). On the other hand, participants commented that the verbal (i.e., voice, tone, and content) and body languages of certain NPCs were uncharacteristic in comparison to typical university students in the sampled university. One of them said, “They won't be so rude. Students in high school may be.”

The lack of reciprocity and contextualization in NPC-initiated interactions necessitated the inclusion of avatars to facilitate the lecture-related instructor-student interaction. For example, a participant commented on the lack of content-specific queries from an NPC, “He said he didn't understand, but I would need more details as to why and what he didn't understand.” When acting as virtual students, participants were found to be attentive and proactive in questioning their peers on the content lectured. Viewing others' teaching performance also stimulated the intent to self-evaluate one's own teaching. Multiple participants had requested the feedback and the review of their teaching archives after viewing others' teaching performance.

4.4.3. Embodied gesturing and walking

Kinect-enabled gesturing was well observed and documented during participants' virtual teaching process (as reported in the previous sections). Another frequently-mentioned component for embodied presence in the MILE was walking, which can be illustrated by a participant quote – “I like to interact with each individual student. I will walk to them.” Walking toward and among students while talking was reported as a preferred interactive teaching style by multiple study participants. Yet the scope and distance of walking was somewhat constrained by the limits of the Kinect sensor. A walking zone was hence marked out on the ground of the conference room; participants had to check this physical boundary while walking and talking. Free movement, thus, was not a natural occurrence.

Another salient design feature related to the embodied presence in the MILE is the point of view. In the virtual world, participants

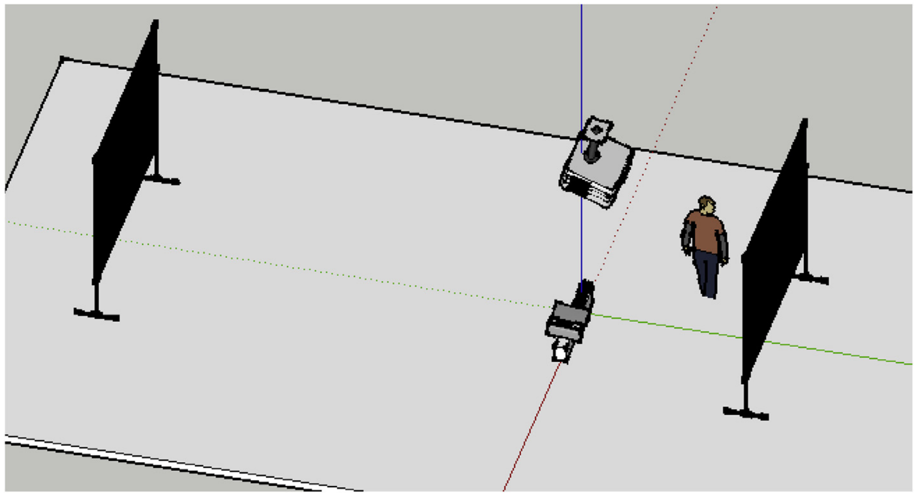

Fig. 3. Conceptual depiction of MILE-based lecturing.

were able to shift between a zoom-in, first person view and a zoom-out, third-person perspective. Some preferred the former because they would like to have a close-up view of their virtual students, to "have (simulated) eye contact with students," and to avoid seeing their own gesturing "because it is distractive." Others preferred the latter so they could better track the whole class. The shifting between the first-person and third-person views, however, was controlled via an external Bluetooth mouse, which created another impediment for the embodied presence.

5. Discussion and conclusions

5.1. Discussion

This current study, supporting the prior research on the mixed-reality integrated teaching training for pre-service teachers (Hayes, Hardin et al., 2013; Hayes, Straub et al., 2013; Liarokapis & Anderson, 2010), has provided preliminary evidence on the applicability of the mixed-reality integrated teaching training in the higher education setting. Different from the mixed-reality arrangement in prior research, the MILE in this study involves only open-source software, low-cost technology, and a daily conference room set-up. Hence it is fairly accessible and transferrable to be implemented in other universities or schools.

The finding on study participants' satisfaction with and active practice of Kinect-based, avatar-embodied live gesturing for lecturing is particularly encouraging. Creating digital avatars who track and render users' gestures in a collaborative virtual learning environment hasn't been reported in prior research (Bailenson et al., 2008). This study indicated that the emerging, commercial body sensory technology can be integrated into a virtual-reality-based simulation to create a mixed-reality learning space and enable embodied presence. In this study, users can naturally convey live representational, pointing, and beating gesturing via their avatars during the process of virtual instruction. Based on the situated and embodied cognition perspectives (Anderson, 2003; Brown et al., 1989; Shapiro, 2010; Wilson, 2002), a potential hypothesis to be further investigated is that the embodied gesturing during virtual teaching may reinforce not only embodied presence, but also the conceptual representation of the content topic and hence pedagogical content knowledge development for the teaching trainees. On the other hand, the Kinect sensor cannot fully support the embodied, free walking/talking, or the gazing-based joint attention among a virtual class. Hopefully, the forthcoming sensory and augmented-reality technologies can address these functionality issues to enhance the affordance of a MILE for creating the embodied presence.

In this study, the prevalence of lecturing-oriented teaching actions may be due to the pre-selected teaching scenario (i.e., lecturing on a self-chosen content topic), the prevalent teaching belief among teaching trainees, and the lack of reciprocity in agent-initiated interactions. Potential design improvements are: (a) taking advantage of the open-endedness of the virtual reality to develop a variety of teaching scenarios to suit disciplinary and teaching-style differences, or inviting the participatory design of the teaching trainees in teaching scenario development; and (b) customizing the artificial intelligence scripts to enhance the reciprocity and adaptiveness of the agent-related interactions, while arranging a balanced mixture of agents and avatars in the virtual world.

Overall, our empirical findings on the salient features and constrains of the current MILE as an immersive teaching-training platform are in agreement with the claim of Bailenson et al. (2008) and Dede (2009) that we can create immersion and sense of presence via the environmental fidelity in the three-dimensional virtual space, provision of virtual actions, and emotional experience activated by the archetypical scenarios in the virtual space.

5.2. Conclusions

The study suggested that a mixed-reality integrated learning environment (MILE) will reinforce sense of presence and potentially act as an immersive platform for active teaching training. Presence survey and interviewing responses, user interactions, and eye-tracking results all indicated that participants were engaged and immersed in the VR-based, Kinect-integrated teaching practice. In the MILE, participants have accomplished an ample range of teaching tasks/actions and performed a succession of avatar-embodied live gesturing during virtual teaching. Although there is no enough statistical evidence supporting the effect of the two-hour MILE intervention on teaching self-efficacy, participating GTAs tend to develop a better understanding and awareness of the challenge of classroom management. Moreover, the study found that the environmental fidelity and the integration of the virtual and physical learning spaces, the design and arrangement of virtual agents and avatars, and the affordance of embodied gesturing and walking are salient design features that affect participants' sense of presence and their virtual teaching performance.

5.3. Limitation and future research

This mixed-method study mainly collected behavioral and qualitative evidence on the potential effectiveness of the MILE with a relatively small sample. The impacts of the MILE on sense of presence, teaching competence, and other teaching skills should be further investigated via an experimental comparison study. Future research should also examine the ways that other emerging body sensory technologies can be used to provide a valuable avenue for the design of an immersive learning environment, and the corresponding design features that promote situated learning and transfer.

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