Enhancing discipline specific skills using a virtual environment built with gaming technology

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This article describes use of a virtual environment in a multi-disciplinary context to enhance discipline specific skills. A virtual environment built by reusing gaming technology was modified in a collaboration across Computing, Construction Management and Nursing & Midwifery disciplines. A two-staged pilot evaluation considered (i) a construction management cohort engaged with regulatory building inspection critically analyzing their environment to determine compliance and (ii) a nursing cohort, building occupant's experience in a virtual fire drill. Feedback from cohorts was used to improve the virtual environment and reflect on the use of simulations in this context. Results suggest students appreciate graphical realism in the simulated environment and the ability for the virtual environment to enhance practicality in learning and to contextualize theory.

Keywords: Simulated work environment, virtual environment, work-integrated learning, simulation, gaming technology

Work-integrated learning (WIL) has been acknowledged as a mechanism to achieve a balance between theory and practice through the integration of academic learning to workplace application (Stoker, 2015; Wilton, 2012). Ultimately, the intent is to prepare graduates with the aptitude and employability skills to effectively engage within the work environment upon graduation (Brimble, Cameron, Freudenberg, Fraser, & MacDonald, 2012; Cameron & Klopper, 2015; Freudenberg, Brimble, & Cameron, 2010, 2011; Gribble, Blackmore, & Rahimi, 2015; Jackson, 2015; Stoker, 2015). However, the administration of WIL programs to support students to learn discipline specific skills in a practical context is not without impediments.

Firstly, the educational establishment needs to deal with any potential liability for instance risk associated with duty of care, noncompliance of their establishment rules, as the control of students in most instances is moved to an external organization (Swift & Kent, 1999; Cameron & Klopper, 2015). Moreover, the legal risk is associated with issues around confidentiality, privacy and negligence (Cooper, Orrell, & Bowden, 2010) which also adds to the concerns. Secondly, specifically for WIL programs in the construction sector, on-site programs are acknowledged for operating in high risk and hazardous environments (Safe Work Australia, 2015), where safety, risk, and liability significantly hinder realistic on-site exposure opportunities. Finally, large student cohorts with mixed mode delivery (on-campus and distance cohorts) presents an additional level of complexity (Freudenberg et al., 2011; Schuster & Glavas, 2017) with issues such as location and the requirement to provide an equitable experience across cohorts impeding opportunities.

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The use of virtual environments and simulated activities has been identified as a mechanism that has the potential to overcome many of the traditional WIL problems and restrictions (Al Shehri, 2012; Çalişkan, 2011). There is increasing interest in providing simulated or virtual experiences that facilitate engagement with authentic work-oriented practices (Jackson & Jones, 2019; Schuster & Glavas, 2017) and allow students to acquire experiences critical to their future careers (Patiar, Ma, Kensbock, & Cox, 2017; Seifan, Dada, & Berenjian, 2019). However, one issue is the time consuming nature of virtual environment development (Smith & Trenholme, 2009). Fortunately, much of the functionality needed for a virtual environment is already implemented in common game engines, which serve to greatly minimize the costs involved (Marks, Windson, & Wünsche, 2007; Trenholme & Smith, 2008; Vogel, Greenwood-Ericksen, Cannon-Bowers, & Bowers, 2006). Therefore, customization of a computer game environment with building model information has the ability to create a realistic virtual environment to maximize learning and enhance critical thinking capabilities while overcoming the difficulties of the more traditional work experience programs.

This paper describes the use of a virtual environment in a multi-disciplinary context to enhance teaching discipline specific skills of construction management and nursing students through the use of a simulation of an actual building. One aim of the project was to explore how the different disciplines could contribute expertise to provide WIL-like experiences as an educational goal. Firstly, a computer game engine was used to develop a virtual prototype of a real-world building. Next, a construction management cohort completed a virtual regulatory building inspection critically analyzing their environment to determine compliance. The aim was to provide a highly authentic task in a virtual setting (Bosco & Ferns, 2014). To further develop the virtual environment as a teaching tool for construction management students, it was also presented to a nursing cohort - hypothetically the 'building' occupants - to obtain their observations in the context of virtual fire evacuation drills. The results favored the simulated environment's ability to enhance learning and subsequently to contextualize theory.

VIRTUAL ENVIRONMENTS IN PRACTICAL LEARNING

The term virtual environment is defined as "a synthetic, spatial (usually 3D) world seen from a first-person point of view. The view in a virtual environment is under the real-time control of the user" (LaViola, Jr., Kruijff, McMahan, Bowman, & Poupyrev, 2017, p. 8). According to Al Shehri (2012) the simulation of the real-world involves varying degrees of immersion: "…a high degree of interaction between the user and the VR system" (p. 338). The use of such a system allows students to have the opportunity to experience the work environment without entering a potentially hazardous operational environment. The virtual environment is ultimately a simulation of the real-world environment where the inclusion of computer-controlled avatars and communication channels enhance immersion and educational capabilities through the creation of an interactive environment to enhance the learning experience (Eschenbrenner, Nah, & Siau, 2009).

Virtual environments have been implemented across many educational domains due to the potential opportunities to contextualize theory and practice (Livingstone, Kemp, & Edgar, 2008). Wiecha, Heyden, Sternthal, and Merialdi (2010) support the use of virtual environments within medical sciences given the many opportunities they provide as a teaching tool to enhance learning outcomes. Similarly, Gribble et al. (2015) observed that WIL can enhance the employability of international students through development of social and cultural capital. Essentially, virtual environments offer unique simulated experiences and their use is well suited to education programs (Chen, Toh, & Ismail, 2005). The combination of virtual environments and student work experience has benefits such as authentic interactivity; flexibility; constructivism; wider availability; equal opportunity platform; and safe, customizable and low-cost environments (Al Shehri, 2012). However, such environments are by no means without their limitations – including user interface anxiety, the need for user training and assessment value (Al Shehri, 2012) but are still worthwhile particularly when associated with high risk work environments such as construction management.

The Virtual Environment

Smith and Trenholme (2009) used the Source Engine (Valve Corporation, n.d) to create a virtual environment focused upon an emergency evacuation fire drill scenario. The virtual environment utilized the same game engine as the Half-Life 2 video game (Valve Corporation, n.d.). Floor plans of a three-story real-world building (the Computer Science Department, Durham University, United Kingdom) were used to determine the layout and relative scale of corridors, doors and rooms. Elements in the real building that would act as audio and visual cues to someone during a fire evacuation were identified in the department and their positions added to the plans so that they could be accurately included in the final model. These included fire alarm triggers, fire alarm sirens, fire exit signs and fire extinguishers. Photographs of various areas of the department were taken to aid texturing the virtual environment (Smith & Trenholme, 2009). The environment was modelled with the inclusion of appropriate materials and graphics to create practicality in learning. Figure 1 provides an illustration of the virtual environment created from the actual building.

FIGURE 1: The virtual environment with example corridor (left) and simulated fire event (right).

Modifying the Virtual Environment

The Smith and Trenholme (2009) virtual environment was modified to support the learning task for a Construction Management cohort. Modifications involved removal of fire services to create an inspection environment considered not compliant with regulatory building codes. Variations to the initial environment involved the removal of signage from exit doors and within paths of travel to exits, and the deletion of portable fire extinguishers and applicable signage. Fire events from the original simulation were also removed. Figure 2 provides an illustration of the original virtual environment against the modified virtual environment.

FIGURE 2: The virtual environment with example original (left) and modified views (right).

From the 3D building model, a set of floor plans were extracted and adapted to suit the teaching curriculum assessment (Figure 3). Primarily this concerned the regulatory requirement associated with building access and egress, for example, focusing upon exits and paths of travel to exits.

DISCIPLINE CONTEXT

Construction Management : The National Construction Code

Within Australia, the National Construction Code provides the requirements for safety, health, amenity and sustainability in terms of both new building design and existing building modifications. The Code incorporates the Building Code of Australia Volume One which establishes the technical provisions for building work in Class 2-9 buildings: multi-residential, commercial and industrial style buildings, whilst allowing for variations in climate, geographic and geological conditions (Australian Building Codes Board, 2016).

The Code is administered by Australian States and Territories through their relevant planning and building legislation as these regulations set the legal framework for planning, design and construction of buildings. In particular, they set the detail pertaining to construction and occupancy certificates, building inspections and regulatory enforcement. Building surveyors accredited as certifiers, whether working for local government authorities or the private sector generally have the delegated powers under the legislative frameworks to determine whether building work complies with the Code (Australian Building Codes Board, 2016) and to action accordingly.

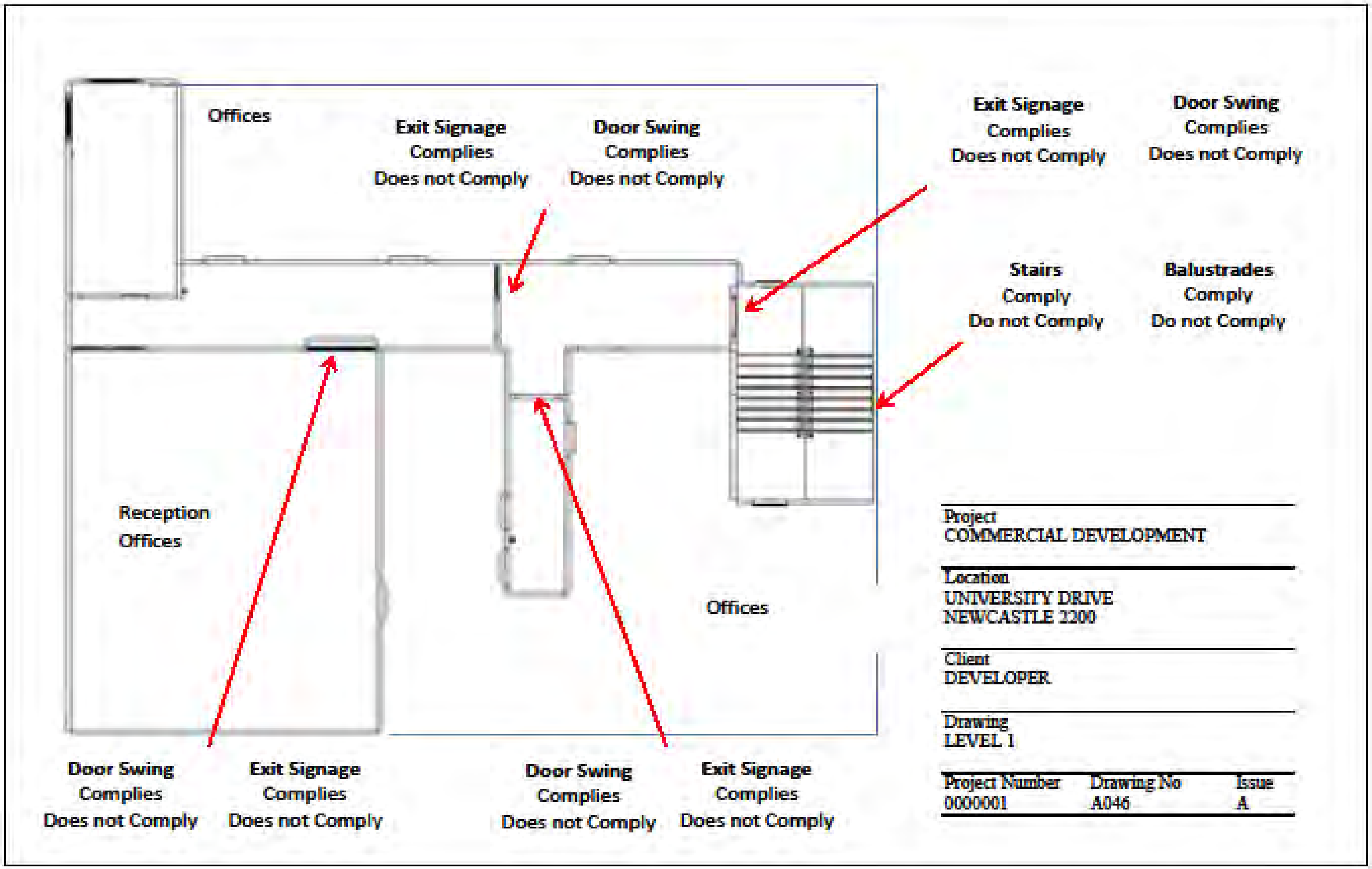

FIGURE 3: Example extracted floor plan with labelled learning tasks.

Nursing: Evacuation During Emergencies

Evacuating healthcare facilities in New South Wales (NSW) during natural disasters is guided by the NSW State Emergency Management Plan (EMPLAN) (Cappie-Wood, 2018) with similar plans in other Australian states. The Australian Government has an overarching policy for the management of disasters in the National Health Emergency Response Arrangements (Australian Government Department of Health, 2011). Local procedures for evacuation of a health care setting are more difficult to secure. Evacuation procedures are usually a component of staff orientation. However, actual evacuation exercises are often a missed activity (Löfqvist, Oskarsson, Brändström, Vuorio, & Haney, 2017) and in complex healthcare environments arranging evacuation exercises are difficult (Golmohammadi & Shimshak, 2011).

The focus of health care facilities is the care of people who have significant health problems and who often require acute and continuous care. Thus, evacuation of patients and personnel presents challenges different from the ones in traditional emergency evacuation (Chen, Guinet, & Ruiz, 2015). Given the varying levels of disability in patients and the anxiety associated with illness, training for such events with evacuation drills would not only be disruptive to treatment but has the potential to cause significant harm and even death. Use of simulation technology for nursing students is an ongoing educational trend (Overstreet, 2008) and can promote theory-practice integration (Botma, 2014). Virtual environments have a number of advantages in this setting. Simulated exercises provide a hands-on experience and provide opportunities for reflective debriefings (Overstreet, 2008). In the context of emergency evacuations, patient safety is paramount and virtual environments can be deployed to be accessed at any time thus allowing staff to choose the most appropriate time for the training with no distractions to the healthcare environment (Farra et al., 2019).

RESEARCH METHODOLOGY

The research followed the world view of constructivism with a phenomenological approach or mode of enquiry. The constructivist view and phenomenological approach aligned well with the research as they enabled a true exploration of the phenomena: to understand the perspective of the students – their experience from a first person view (Quinlan, 2011) and an assessment of the capabilities of the scenarios provided by the virtual environment to enhance learning within the realm of regulatory building codes.

The project employed a qualitative exploratory research design. Aligned with the constructivist view point, the design provided for a greater depth of understanding (Bryman & Bell, 2011) of both individual and group views and subsequently evaluations across two discipline cohorts to inform future development of the virtual environment and assess suitability to simulate a WIL-like experience.

Case Study

Construction management degree programs in New South Wales (NSW), Australia, are typically accredited by the Australian Institute of Building Surveyors and are approved degrees under the State of New South Wales Government, Building Professionals Board. Therefore, students who complete such degrees have the opportunity to work as professional building surveyors and building certifiers as they have met the educational requirements of the institute and regulatory body.

Building codes and compliance courses are fundamental within construction management degrees and provide students with an introduction to the world of regulatory building codes and compliance activities with a primary focus upon fire safety. However, to amalgamate theory with practice and ensure a deeper understanding of regulatory application, site visits are necessary. WIL in terms of building regulation is often harder to accomplish than in standard construction management courses given the regulatory implications for building owners where non-compliances are detected. Therefore, a virtual environment that enables a student to undertake a real-world regulatory inspection holds promise for construction management students and their study of building codes.

Two Staged Data Collection Process

The design and development of the scenarios for use in the virtual environment was a collaborative approach involving three disciplines: Construction Management (Maund, Hilaire, Gajendran), Nursing and Midwifery (Lyneham, Geale) and Computing & IT (Smith) (Figure 4). The pilot evaluation involved a two-stage process.

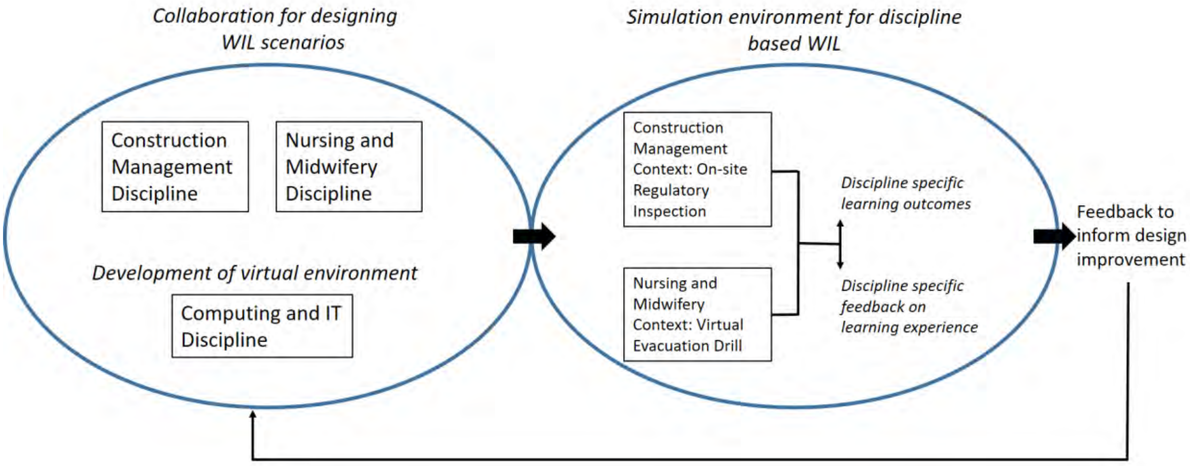

FIGURE 4: WIL scenario and simulation environment development process through interdisciplinary conceptualization and operation.

Stage 1: The modified, and non-compliant, virtual environment was deployed to a construction management student cohort. In this scenario, the cohort had discipline specific learning outcomes in which virtual environment tasks were aligned with course curriculum. Using building regulatory theoretical knowledge, the students were required to complete a virtual regulatory building inspection critically analyzing their environment to determine compliance. Interviews were then conducted to obtain an understanding of simulation-based experiences across navigation, visualization, assessment capabilities and learning outcomes. We used the more general definition of navigation to include physical travel in the virtual environment and the intention to move and selection of travel waypoints (LaViola et al., 2017, p. 318). Also, all navigation in the virtual environment was free moving, that is, non-guided (Chen, Toh, & Ismail, 2005).

Stage 2: The original, simulated fire drill, virtual environment was presented to a nursing student cohort - hypothetically the 'building' occupants - to obtain discipline specific feedback. The nursing students were required to navigate the virtual environment and evacuate upon hearing the fire alarm, during which time they encountered virtual fire events. Focus groups were undertaken to understand their discipline specific experience to inform learning opportunities with the virtual environment.

Ethics approval for the participant studies was granted by the University of Newcastle (Australia) Human Research Ethics Committee.

Stage 1: Construction Management Context

Written informed consent was obtained from each participant prior to their involvement. Participants were over 18 years of age and enrolled in a relevant construction management degree and had completed a course on building codes and compliance.

Each participant was individually shown into the testing room and seated at a desk with a desktop computer: Dell Precision T1600: CPU 3.40GHz, with Dell UltraSharp U2412M 24-inch monitor. To accustom participants with navigation within a virtual environment they were first provided with a five-minute introduction to navigation using a virtual environment demo in the Unreal Engine (Epic Games, n.d.). The intent was to ensure all participants were familiar with navigation in a similar virtual environment without being exposed to the virtual building used in the test.

Participants were then provided with the following documentation:

- Architectural plans: floor plans for each building level and a section view that nominated areas for inspection and assessment.
- Extracts from the Australian National Construction Code, Building Code of Australia Volume One, applicable to the areas under assessment: Section A General Provisions, Part A3 Classification of Buildings and Structures; Section C Fire Resistance, Part C1 Fire Resistance and Stability; and Section D Access and Egress, Part D1 Provision for Escape and Part D2 Construction of Exits. Note: The design of the Code requires that the building first be classified and the *rise in stories* and *type of construction* determined prior to progression to Section D.
- A two-page document outlining the scenario and containing questions to be answered. The questions were divided into two parts: those answered using the Code and the plans against those that could only be answered using the Code and the virtual environment (see Table 1). Code questions were focused upon reinforcing basic principles given the first year student cohort – to enhance learning and provide a realistic learning experience rather than present complex scenarios.

TABLE 1: Example questions from Australian National Construction.

National Construction Code: Building Code of Australia Volume One		
	BCA Clause	**Question**
Section A General Provisions	Clause A3.2	Determine the Building Classification
Section C Fire Resistance	Clause C1.1	Determine the Type of Construction
	Clause C1.2	Determine the Rise in Stories

The scenario placed each participant in the role of a building surveyor undertaking a regulatory inspection of the simulated building. They were given five minutes to review the documentation supplied before the test commenced. Twenty minutes was allocated to navigation in the virtual environment and completion of all set tasks.

Upon completion of the exercise, participants were individually interviewed regarding their experience with the virtual environment, and specifically in relation to the set tasks. Interviews were semi-structured in nature. Initial questions concerned demographic data, while remaining questions concerned feedback across the areas of navigation, visualization, assessment capabilities and learning outcomes.

Stage 2: Nursing Context

Written informed consent was obtained from each participant prior to their participation in the project. Participants were over 18 years of age and were second- or third-year students enrolled in a nursing degree as they had attained site experience at this stage of their studies.

Following the process for Stage 1, each participant was individually shown into the testing room and seated at a desk with a desktop computer. Participants were required to navigate through the virtual building to the third floor and upon hearing the emergency alarm evacuate the building. They undertook this exercise three times: once with only one exit blocked by fire, once with multiple exits blocked by fire and once with all exits blocked by fire.

Participants were allocated fifteen minutes to complete the task: Upon completion of the task participants attended a focus group to discuss their experience and provide feedback on the environment. Each focus group involved 2-3 participants and had a forty-five-minute duration.

As virtual environments can be perceived by users as very real experiences, there was a concern that the presented virtual fire drill could result in a reaction similar to a real event. For example, the participants may experience a fight or flight response and have an adverse emotional reaction if they made a navigation choice that resulted in exposure to the virtual fires. Participants were therefore debriefed immediately following the virtual exposure to determine if they felt or showed signs of distress. Debriefing was conducted by a specialist in clinical health and disaster management.

RESULTS

Stage 1 Results

All participants met the inclusion criteria, that is, currently enrolled in relevant degree and had completed a course on building codes and compliance. A total of six (n=6) participants were involved in the trial with an age range of 20-44 (average age 30).

Gaming experience differed considerably across the participant group: no prior experience (n=2), frequent use (n=3) and master (n=1). Those familiar with gaming technology conveyed experience with a range of devices: keyboard, mouse and joystick. All participants indicated daily computer usage.

All participants completed the set tasks within the twenty-minute allocated timeframe. In addition, they used all sources of information provided to answer the question sets. An interview was conducted with each participant immediately after the testing period.

The feedback from participants was positive. When asked about the realism of the virtual building, Barney (CM student) noted "for what you need to achieve it is a great platform" and Isaac (CM student) commented that it was "as good as possible". Other feedback primarily concerned the following areas: ease of navigation, practicality in learning, alignment with curriculum and professional application. Participants also identified two areas for consideration in future environment modifications: the inclusion of a navigation map and color coding of doors (as doors were locked to restrict access to parts of the building that were not modelled in the virtual environment).

Stage 2 Results

All participants met the inclusion criteria, for example, were enrolled in a nursing degree and were at the second- or third-year level of their studies. A total of eight (n=8) female participants were involved with this stage of the research: two groups of three participants and one group of two participants. Gaming experience consisted of no experience (n=2) through to minimal experience (n=6).

All participants, apart from two with no gaming experience (see Discussion: Navigation), completed the set activities involving fire drill evacuations. Following which they participated in a focus group to provide feedback on their experience. Similar to the first participant cohort, the feedback was positive with the virtual environment identified by multiple participants as a tool which could assist professional learning, that is, industry emergency management training. Lilith (nursing student) noted:

> I thought it was great. I really did. I thought it was - I watch my son play Minecraft and all these computer games and it was exactly like that. Me, personally, I found it difficult walking into walls and opening doors, because I don't play a lot of computer games, but I feel like if you were directing that at a younger population, they would get a lot out of it.

"Aurelia" (nursing student) commented that "the idea is good … the concept of being able to train people through a virtual reality is good". Other major feedback themes concerned enhancing practicality in learning discipline specific skill sets, engagement, and learning capabilities. Participants highlighted that the use of additional sound interference (i.e., people talking), computer controlled human avatars and suitable fixtures would help to create a more realistic environment to emulate professional practice.

DISCUSSION

The results suggest that use of a virtual environment in a multi-disciplinary context can support teaching discipline specific skills. The collaboration between the Construction Management, Nursing & Midwifery, and Computing & IT disciplines enabled the development of scenarios for a realistic virtual environment for facilitated practical learning with multi-disciplinary cohorts for a WIL-like experience. Six topics on the virtual environment that emerged from collected data are discussed as follows:

Navigation

Construction management participants positively favored the virtual environment in terms of its ease of use and navigation capabilities, even those with no prior/minimal gaming experience. When asked about the navigation in the environment, Gordon (CM student) noted that it was "great. Enjoyed and it really related to the course". This was similar across nursing participants with Tina (nursing student) observing that "after the first little bit, it got easier to navigate it, once you got the hang of it". However, two of the nursing participants showed great difficulty with navigating within the environment. Although the introductory gaming session prior to the testing was considered satisfactory by most participants across the cohorts to achieve a level of aptitude needed to complete the assessment tasks, there needed to be more consideration of prior gaming experience for the two nursing participants to ensure the maximum learning experience. Maya (nursing student) noted "I wasn't really thinking about evacuation procedures. I was more worrying about being able to get up and down things" indicating that the use of the gaming technology impacted her focus on the evacuation task.

Previous gaming experience is an increasing issue with the use of virtual environments for learning. Limited prior experience can impact learning opportunities. However, additional pre-training can significantly help users with less prior experience (Frey, Hartig, Ketzel, Zinkernagel, & Moosbrugger, 2007) and thus ensure students are ready to engage with the target learning environment. Although previous gaming experience can improve interactions with gaming technology (Smith & Du'Mont, 2009), gaming experience can also negatively bias a student's approach to the learning material, with gamers considering environments more as a game, rather than a real-life simulation (Smith & Trenholme, 2009). This bias can be amplified through the use of game engines to build the virtual environment where gamers are already familiar with the underlying technology being used. Thus, the reuse of gaming technology may come with a loss of veracity in the learning experience.

As noted, pre-training in the form of increasing the introductory gaming session prior to testing will likely help with a lack of gaming experience. Also having a threshold of competency before the learning scenario can be helpful. In the initial use of the fire drill system (Smith & Trenholme, 2009), participants had to navigate up three flights of stairs to a staff room before a fire alarm would sound. Thus, participants had already demonstrated competency with navigation controls before the main scenario started.

Removing previous experience bias is more difficult. However, providing appropriate pre-session information, for example highlighting the serious nature of the simulation may be appropriate. Also penalizing inappropriate game-type behavior may help students better engage with the virtual environment, for example allowing only one attempt per scenario, that is, no re-spawning on 'player death'.

Realistic Learning Environment

The realistic nature of the virtual environment was an area that received significant attention by all participants. The building design, colors and textures through to the furnishing and fixtures were considered of a nature that invoked realism and contributed to participant engagement. Walking capabilities, door movement (involving footstep and door hinge audio) were highly regarded and considered to emulate a real building given the 360-degree viewing. Maya (nursing student) observed that "You really did get the feeling that you were moving through somewhere. You could hear yourself and the door opening . . .". Also the realism of the fire simulation was considered with Athena (nursing student) commenting "a few times I went near the fire and it was making that noise. So it felt like I was getting burnt [laughs]". Construction management participants commented on how they "forgot" it was a gaming environment and considered themselves to be in a real building undertaking a regulatory inspection. However, Alyx (CM student) considered the scope of task in the virtual building noting that "time is needed to undertake the tasks and familiarize yourself and then test" and "time needed to orientate yourself before you undertake the assignment".

Engagement

Aligned with a realistic environment, engagement with the simulated building evoked favorable responses across both cohorts. Lilith (nursing student) noted "I felt like I was in an evacuation. I think it was, the skills that I hoped I had, they came to me as soon as I was in that situation, I thought about them". All participants across both cohorts identified that they were engaged apart from two nursing participants. Participants who did not identify as having an engaged experience explained that their lack of gaming and computer experience impacted upon their ability to undertake tasks. Therefore, they were focused on how to navigate and identified significant frustration with this process which impacted upon these activities. Nisha (nursing student) observed that "I think I was going the right way and then I'm on the wrong button, so I'd be spinning around. I'm not moving forward. I was - yeah it was just the fact that I couldn't get it".

Most nursing participants mentioned a commitment to the experience and engagement and concentration upon evacuation creating a real-world experience. Nisha (nursing student) noted "I kept thinking because in my head I kept thinking, if this was real yeah I would be burnt by now". To many it was not considered to feel like a gaming environment. The navigation abilities of the system and environmental realism, from sound enhancements and viewing capabilities, impacted upon their experiencing the simulation as that of an actual building with Maya (nursing student) commenting "You really did get the feeling that you were moving through somewhere. You could hear yourself and the door opening".

Within the nursing cohort the engagement created a sense of anxiousness and urgency amongst most participants. This was particularly true during the evacuation process as they tried to remember pathways and were confronted with locked doors while faced with fires at various exit points. Given that the construction management cohort task involved completion of professional tasks in a relatively sterile environment, the environment did not evoke such anxiety responses.

Alignment with Curriculum

Within building codes and compliance courses, assessment items commonly involve a critique of 2D drawings and the ability to understand on-site practices and regulatory site inspections is limited. The virtual environment was seen as beneficial as it added a new dimension providing professional experience. The scenario tasks were designed to be aligned with the theoretical knowledge undertaken within such courses. From working out classification, rise in story, type of construction through to clause specifics, all participants identified that the tasks and the manner in which they were presented aligned well with course theory and existing assignments; therefore, contributing to and providing context to enhance their learning experience. When asked about whether the models provided the facilities to enable assessment of non-compliance issues Gordon (CM student) noted that the "types of questions are correct for the course content. Having non-compliances is good" while Wallace (CM student) commented that "first year students would go well" and Isaac (CM student) observed that it was "good as a teaching aid".

Professional Application

The environment was considered a tool that would contextualize theory with practice and prepare students for their professional career, that is, simulating authentic work-oriented experiences (Jackson & Jones, 2019). Multiple participants made comment on the benefit of undertaking such virtual exercises to industry application. They commented that their theoretical knowledge and experience would be significantly enhanced through interaction with the virtual environment. There was a valuable contribution from both student cohorts in relation to the theme of professional application. Firstly, construction management students explained that their use of standardized 2D drawings to emulate professional practice was significantly enhanced by undertaking a regulatory inspection. Furthermore, undertaking an inspection within the environment enabled students to feel better prepared for industry having undertaken such an activity and knowing what to look for and consider on-site. Barney (CM student) commented that "once [I'd] id [identified] an issue [I] then keep looking at other areas for it also".

Secondly, although not the true focus of this research, multiple nursing participants explained how training in evacuation is often limited in many health care environments due to patient mobility and some participants stated that they did not know what to do if faced with an emergency evacuation scenario as they had not been exposed to evacuation drills. Lilith (nursing student) commented that "I think generally most workplaces do your fire tour on the first couple of days when you are really not taking that in. You're taking in who's around you and what your physical job is day-to-day" and Tyreen (nursing student) noted "it was just a bit of an eye opener. You don't really think it's important to know your surroundings and stuff. [Real life] Fire evacuation things are pretty boring when you go through them . . .". Hence, the environment was considered a beneficial learning tool to aid understanding of emergency protocols and evacuation. Lilith explained ". . . it gives a pre-programmed route in your head and I think that could potentially save lives".

Even the two nursing students who had difficulty with navigation concurred with the comments by other participants. The environment was seen as a mechanism to raise awareness of fire safety and options available for emergency egress (Löfqvist et al., 2017). Participants noted that facilities are always different and areas designated to work change; therefore, as a training environment it was considered beneficial to reinforce the work area layout and practice possible evacuation routes. Amara (nursing student) commented that:

> I'd say that - yeah - well it makes me think of an actual situation where I'm about to - if I'm working as a nurse in an aged care facility, as the focus of this exercise is - I don't really know my way around. How am I going to be able to just look after myself and the patients at the same time? That's very scary to me.

Suggested Improvements

Two primary modifications suggested by construction management participants involved a navigation map and color-coding doors to indicate locked status. Gordon (CM student) noted that an enhancement would be for "doors [that] can't open in a different color to others", Eli (CM student) suggesting to "integrate a map [to] north point to help orientation" and Isaac (CM student) noting that a "map in bottom view would be nice." Although a navigation map may appear suitable within a virtual environment, for the purpose of the assessment it was not included to ensure the exercise was able to appropriately simulate a real-world experience. In many situations, a certifier may undertake a building inspection where visual aids such as architectural drawings are not available (i.e., assessment of a heritage building) and reliance on paper plans or modern building tools can be an issue. Some students explicitly noted this in the context of identifying non-compliance with Isaac (CM student) commenting "easier to review plans though" and "not good as a BIM [Building Information Modeling] checking tool, i.e., easier with paper plans and schedules". However, as noted above, if accurate building plans are not readily available, providing experiences of on-site compliance checking, as made available in a virtual building, fill a required workplace capability. The exercise also assisted with learning navigation skills in covering the complete layout of the building to be inspected.

Similarly, in relation to the color coding of doors, within the real-world environment doors locked and unlocked would not be colored differently; therefore, to ensure a realistic exercise such differentiation of door types was not considered suitable. Interestingly, the nursing participants favored modifications to include sound interference and inclusion of computer controlled human avatars to create a more realistic experience. Maya (nursing student) commented that:

> So that the alarm is going but if you had other voices and people saying, well you know what are we going to do? What happens now? Even if you can't talk back to them, that would still give you that feeling of what's happening in a - yeah, that sort of scenario.

Tina (nursing student) observed that “there's no residents or anything to worry about though - in that. Maybe if you had to collect so many residents on your way out or something”. These modifications will be important to future development of the environment as it is acknowledged that inspections are often conducted in ‘busy’ rather than sterile environments which would present a more realistic teaching environment in simulated buildings.

CONCLUSION

The research reported here describes the reuse of a virtual environment built with gaming technology to enhance practical WIL-like learning experiences for construction management and nursing students and demonstrates the benefits of diverse disciplines coming together to solve multiple education goals. The learning scenarios in the virtual environment were developed in collaboration with three disciplines and evaluated with target student cohorts in a pilot evaluation.

Stage 1 involved a construction management student cohort where participants navigated the virtual environment and completed a regulatory building inspection: completing set tasks and identifying instances of non-compliance. Following which participants were interviewed to obtain their experiences. Stage 2 involved a nursing student cohort, considered the ‘building users’, who were required to navigate the virtual environment and evacuate during a simulated fire drill. Focus groups were held upon completion of the activities to further explore student experiences using the virtual environment and to inform future design work.

Overall the virtual environment was received favorably by both cohorts. Primarily the building surveying students saw a strong alignment with their building codes course and considered the simulated environment as a tool to enhance their theoretical knowledge, contextualizing material and providing a real-world inspection experience, thus preparing them for their professional careers. Both cohorts favored the realism of the environment and its ability to contextual theory and enhance learning. It was highlighted that the virtual environment and defined scenarios were considered a benefit to prepare students for their future professions through practical experience. Subsequently, most participants identified a strong sense of engagement within the environment with multiple nursing students identifying anxiety and panic, adding to the realism of the simulated experience.

The experiences of the nursing cohort are extremely important to construction management students, particularly those studying building codes given its focus upon fire safety. Feedback from the nursing cohort provides a deeper understanding of active and passive fire safety measures including fire compartmentation, exits and paths of travel to exits along with the need for compliant stair wells. Integrating this inter-disciplinary feedback to the different cohorts is a topic of future work.

There is considerable scope to the extend the work presented here. The primary use for construction management students could be extended to allow full virtual site visits and potentially visits to buildings at different stages of construction. The secondary use, with the nursing cohort, could be extended to other healthcare disciplines where fire drill training is required. Also, this may benefit other environments where fire drills are prohibitory distributive to run, for example airports, prisons and banks. One issue with the approach is the need to build and/or customize the virtual environment. However, as shown here, the reuse of gaming technology can considerably reduce the overhead with computer game developers providing tools, documentation and source code, either with the game itself or separately available, so that end-users can create new content (Trenholme & Smith, 2008). To some degree, this also emphasizes the need for interdisciplinary collaboration, across domain and technology experts, if the aim to provide ongoing and robust educational experiences supported through technology enhanced learning.

Future research will need to consider assistance to participants with limited to no gaming experience as two nursing students highlighted frustration over difficulty navigating within the environment which affected their ability to become engaged and appropriately complete their tasks. In terms of the construction management cohort, different environments will be produced to mimic real world inspections and be presented to a larger student cohort. Additionally, multiple environments will be considered to reflect buildings both occupied (i.e., with computer controlled human avatars and sound – both active and ambient) against those unoccupied.

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