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SITUATIONAL ELEARNING WITH IMMERSIVE TECHNOLOGIES

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Immersive digital technologies simulate key aspects of the physical world to provide visual, aural, haptic and other cues to the user that create a keen sense of presence or being in the simulated situation. There is broad potential application for such immersive technologies in construction, including the delivery of managed first-person experiences of construction activities where access to actual situations may be problematic or risky. The Situation Engine is an application that makes specific and adaptive practical experience available to users in a hyper-immersive digital rendition of a real-world context. This paper will describe a particular application of the Situation Engine to teaching undergraduate architecture and building students about domestic construction technology in Australia. The paper also reports on a student survey evaluating a trial of situational e-learning with 150 undergraduate students, gauging their views on of their learning experiences with the Situation Engine. There was strongest agreement that this video game technology is useful to a specific understanding of design and/or construction practice, with some reservations over the approach as a replacement for actual work experience.

Keywords: Virtual reality, Simulation, Situation engine, Education.

1 INTRODUCTION

A significant aspect of construction technology teaching and learning traditionally has been the site visit to building projects currently under construction, where students can observe the process and technology of construction work directly in action. However, as class sizes increase, occupational health and safety regulations are tightened, and potential site locations become more distant. The temporal nature of construction means there is only ever a minimal window of opportunity to witness particular aspects of construction technology in action, so it has increasingly become infeasible to provide direct student exposure to the broad practices of construction technology in a realistic setting (Mills *et al* 2006). Equivalent difficulties face all vocational education programs where the practice situation involves potentially dangerous and/or expensive process/technology contexts: emergency response management, invasive health and safety procedures, high-technology manufacturing processes, etc.

In such situations, the potential of replacing direct student exposure with a virtual simulation is apparent. In construction technology education, for example, a number of previous initiatives have utilized a mix of CAD, QuickTime VR, video and interactive multimedia as virtual substitutes for actual site visits (Ellis *et al*. 2006, Horne and Thompson 2008). Such initiatives certainly provide a useful illustration of the technical understanding required of architects and builders in a practice situation. A range of equivalent initiatives specific to other professional contexts have also been developed – see for example, Cameron *et al*. (2009) and Cybulski (2010). However, such initiatives are generally constrained by the particular immersive technologies used, especially in terms of graphic quality, user interactivity, the dynamics of the simulations and how tailored the solutions can be to a given teaching requirement.

The most sophisticated immersive technologies today are found in video games. Particular genres of video games use the highest performance graphics engines to render moving photo-realistic scenes in real-time and 3D, along with the potential for associated surround-sound audio and tactile feedback to a user who controls the action with a variety of input devices. The "action" is in fact variously controlled not only through input devices, but also by the particular rules and properties "coded" into the video game by the developer. Such coded rules and properties can now be extremely sophisticated, and many incorporate models of real-world mechanical behaviors ("physics engines") simulate physical properties such as mass, gravity, velocity, volume, etc. in realistic detail. Objects in such games can variously be opened, pushed, bent, lifted, broken and/or be used to trigger a myriad of other actions. Artificial intelligence and social dynamics are also now being modelled and incorporated to simulate agency and group behavior in the various game "actors". Video games also enable multiple players to operate collectively at the same time. The distinction between massively multiplayer persistent online environments and highly authentic single player environments is expected to collapse in the near future.

What is particularly timely about the potential development of video games for learning and teaching is the fact that the "game engines" themselves (the kernel of coding used to drive a collection of actual game implementations) are being made available on an open-source basis. Even the most powerful game engines can now be acquired free of charge, are intentionally configured to allow third-party modifications to be created and embedded seamlessly into the environment, and are increasingly supported online by a significant and committed community of users and developers.

A number of "serious video games" (a serious video game is one designed for a primary purpose other than pure entertainment) have now been developed as modifications to game engines across a range of game genres. For example, "vehicle simulation engines" have been used to train and test vehicle operators from fighter pilots to crane drivers (Rouvinen *et al*. 2005); "strategy game engines" are variously used for teamwork and project management training; "business simulation games" model economic and manufacturing environments (de Freitas and Maharg 2011). Video game technology has been used to promote student engagement in OH&S for construction (Greuter and Tepe 2013), immersive digital imaging has been used to explain complex engineering situations (Cameron *et al*. 2009), and the ACT-UK has developed simulated construction work scenarios to improve person management skills (Soetanto 2010).

The design and development of any serious video game needs to be evaluated not just as a game, but as a learning technology. As a consequence, the standard design and production process for video games has to be broadened in scope to include consideration of the learning context – within what Luckin (2008) terms a "learner centric ecology of resources". New serious video game initiatives are beginning to forge a more explicit and more specific overarching design and evaluation framework (de Freitas and Jarvis 2006).

This paper will describe the Situation Engine, developed specifically to provide undergraduate building and architecture students with simulated exposure to the broad practices of Australian domestic construction technology in a realistic site setting. The Situation Engine has evolved over several years of formal development and evaluation to a point where it is now being deployed across multiple programs of study in numerous universities in Australia. With each development cycle, new issues are identified and new capabilities added to the system. This paper reports on one particular evaluation cycle, where students who had been exposed to situational e-learning were canvassed on their previous exposure to video games, the relevance of the technology to teaching and learning in general, and its relevance to simulating construction site experiences more specifically. The results of the questionnaire survey are presented and discussed below.

2 THE SITUATION ENGINE

The Situation Engine is an application built using a commercial video game development engine that provides for specific and managed practical construction experiences (a "situation") made available to students (Newton *et al*. 2013). The entire system is provided under a Creative Commons Attribution 3.0 Australia license, and is available for download from http://situationengine.com. Each situation is created as an individual game level, where the context of the level is determined by the 3D models (landscape, buildings, vehicles, artefacts, etc.) incorporated into the scene. Each object is assigned properties (dimensions, mass, articulation, texture, etc.) that determine how it behaves when the game is being played. Scenes can evolve differently depending on the user interactions and starting conditions of each individual use. Other parameters of a scene (light, shading, visibility, etc.) can also be controlled in response to various triggers (time, location, weather, etc.). Triggers can result from user interaction, particular conditions or external data sources, including online websites, internet devices, and physical movement. The Situation Engine is also able to represent actors and behaviors within the scene using a sophisticated rendition of artificial intelligence. Because the system is multiuser, the other actors can also be digital representations of other human users of the system – reflecting the behaviors and actions of other users and placing everyone in a common situation/experience. The Situation Engine is also hyper-immersive, providing a first-person experience with full stereoscopic visualizations using the latest head-tracking devices, location-based 3D soundscapes, body tracking, and haptic feedback (Newton *et al*. 2013).

Figure 1 illustrates an early implementation of the Situation Engine. This situation represents a stylized construction site where students interact with building materials to identify the correct sequence of construction. The building under construction duplicates the building that students are required to construct at 1:50 scale as a group assessment task. The Situation Engine exercise helps students to visualize the building from the technical drawings (blueprints) they receive for their assessment task, and helps reinforce the correct order in which to construct their physical scale models

(Newton and Lowe 2011). A series of other components present students with more forensic tasks to identify incorrect construction detailing, site layout problems, and errors in design. It is targeted more specifically at simulating a site visit, where students can virtually accompany a tutor, take measurements to check building regulation compliance, name components, and identify poor site management and health and safety issues (Newton 2012).

Figure 1. The Situation Engine used to support teaching and learning of construction sequencing.

Figure 2. The Situation Engine used to support site visits and the assessment of technical competency.

Figure 2 illustrates a later implementation of the Situation Engine. This situation takes the BIM model of a typical domestic project home in Australia and renders it at different stages of construction. In this case, the user interface includes a play mode, where a subset of four errors selected at random from a suite of potential errors is incorporated into each separate use of the system. Students are then required to identify the four errors and nominate how each might best be resolved. The potential errors are tied directly to the general teaching curriculum for domestic construction technology, and support a series of quiz questions used in tutorial exercises and subject examinations.

The development of the Situation Engine is predicated on a particular orientation to teaching and learning, known as situated learning (Wenger 1998). Situated learning is an approach to teaching and learning where the development of knowledge and skills is based on the learner actually participating in the socio-cultural practices of a particular domain of professional practice. Teaching in this context takes on a facilitation role, where the onus is on providing students with the skills and opportunities to engage in and reflect on the socio-cultural practices of a profession. Socio-cultural practices are the shared routines, sensibilities, vocabulary, styles, artefacts, procedures, etc. that constitute a particular field of practice: what Schön (1983) refers to as the language, media and repertoire of a particular professional community. Thus, situated learning privileges the act of "being" a practitioner, and is heavily contingent therefore on the availability of authentic clinical experiences. Clinical experiences include such activities as practicums, industry placements, case studies, role play and site visits. The role of the Situation Engine is to provide better-managed, simulated clinical experiences in circumstances where the provision of actual experiences may be prohibited in some way – here termed "Situational eLearning".

However, situated learning is not without its critics (Frank *et al*. 2008). The most substantive issue is that situated learning presumes an epistemological shift from empiricism (a model of storage and retrieval of discrete knowledge) to embodiment (a model of knowledge and learning where understanding emerges through action). Embodiment requires a subjective construction of knowledge, or of thinking on the fly rather than piecemeal storage and retrieval of conceptual knowledge. It also means that testing the outcomes of learning becomes more complicated than just an examination of knowledge retrieval or abstract application skills. Situational e-learning fundamentally is about changing behavior, and for that purpose teaching, learning and assessment must all be action-based.

Like any immersive technology the Situation Engine itself can be, and has been evaluated in technical terms of immersive qualities, user interface design, functionality, efficiency, etc. (Newton and Lowe 2013). However, when the evaluation needs to relate more directly to a situational e-learning context, then the assessment is entirely more complex. The subjective construction of knowledge, which underpins situational e-learning, is as dependent on the level and effort of the student as on the teacher or the learning resource. For the Situation Engine to be effective, the student disposition and motivation is important (Billett 2009). Where learning is perceived to be, for example, of personal benefit, interesting and/or engaging, it more likely leads to richer and more substantive learning experiences. Fatigue, familiarity, complexity and a range of potentially negative personal dispositions and attitudes to immersive technologies will impact the effectiveness of situational e-learning. This includes the attitude of users to the use of new technologies in general, and the pre-mediated experiences of the users more specific to the learning task (Valsiner 2000).

3 THE RESEARCH METHOD AND RESULTS

Luckin (2008) refers to a "learner-centric ecology of resources" to broaden the consideration of new teaching technologies beyond their own technical design. This proposes that the traditional model of technology development must be extended. A design and evaluation framework based on de Freitas and Jarvis (2006) is proposed for the implementation and testing of the Situation Engine. This framework takes the more general form of a structured and rigorous consideration of the context (including the resources available to deliver, access and support the application), learner specifics (including learner attributes and preferences), representation (the form or mode in which the content of the application is made manifest to the user – explicitly, implicitly, vicariously, etc.), and pedagogy (the theory and practice models that frame the learning activities) within which the Situation Engine is to be deployed.

A comprehensive evaluation of the Situation Engine that addresses all aspects of the framework proposed by de Freitas and Jarvis (2006) is currently underway, but this is of necessity a broad and longer-term project. If the influence of all vagaries caused by different contexts, learner specifics, representations, and pedagogy are to be isolated and accounted for, then the scope of the research project required is substantial and ongoing. This paper reports on a single aspect of that broader evaluation project and examines learner attributes and attitudes towards situational e-learning. The aim of the evaluation was to determine the profile and attitude of typical learners to the use of the Situation Engine as a teaching and learning resource, particularly in terms of practice-based, experiential learning contexts. A trial of the Situation Engine with undergraduate architecture and building students in 2012 is used as the basis for the evaluation. The target cohort then comprised students enrolled in the Bachelor of Construction Management and Property, subject BLDG1021 Domestic Construction Technology (total enrolment in 2012: 85), and the Bachelor of Architectural Studies, subject BENV2423 Real-time Interactive Environments (total enrolment in 2012: 65) at the University of New South Wales, Australia.

In order to profile relevant learner attributes a quantitative survey instrument was developed and administered. The quantitative survey was supplemented with a series of open-ended questions to determine learner preferences and opinions specific to the Situation Engine, and to situational e-learning with immersive technologies more generally. The survey instrument comprised eight propositions against which students were required to respond on a five-point Likert scaling from Strongly Disagree (1) to Strongly Agree (5). The first four propositions related to the previous use of video game technology in general and use of the Situation Engine more particularly. This is to determine any relevant pre-mediate experiences of the users:

(i) I am already familiar with the use of a first-person shooter genre of video game engine technology, because I have previously used such games/applications outside of my studies.

(ii) The basic navigation/interface controls for the video game environment are easy to operate.

(iii) The advanced tools and editing functions for the video game environment are easy to utilize.

(iv) I have a sense of where I am and what I am doing within the video game environment.

The second four propositions related to how the Situation Engine might best be applied to teaching and learning. This is to determine the attitude and preferences of users to the use of new technologies in teaching and learning:

(v) This video game technology is useful to my learning experience in general.

(vi) This video game technology is useful to my specific understanding of design and/or construction practice.

(vii) This technology could supplement actual work experience during the period of my studies.

(viii) The activities included in the current application of the video game technology are relevant and useful to my current stage of learning.

In addition, participants were asked for comments in response to three key questions. This provided an opportunity for students to make more specific comments on the potential role of situational e-learning using immersive technologies in their current studies, specifically in terms of their clinical experiences in the construction industry:

(ix) What do you think the best use of video game technology would be in your current studies?

(x) To what extent do you believe video game technologies should be integrated into your curriculum?

(xi) Do you have any comments on the relevance of video game technology to your experience of the construction industry?

A combined total of 113 responses were received, representing an overall response rate in excess of 75%. A summary of the responses to the quantitative questions is presented in Table 1.

The quantitative results indicate that for question (i), only about half (57%) of the respondents were already familiar with the use of video game engine technology, such as the Situation Engine, because they had previously used such games/applications outside of their studies (with an average score on a scale of 1-5 of 3.36). There was strongest average agreement (3.85) with the proposition that this video game technology is useful to specific understanding of design and/or construction practice, which is very encouraging. Similar levels of positive support (3.83) were expressed for the sense of where a user is and what they are doing within the video game environment. Some of the advanced features of the interface were clearly more problematic, though still positively supported the interface overall (3.37). Surprisingly perhaps, some doubt was also expressed over the potential for this technology to supplement actual work experience during the period of studies (3.40). This last point is considered further under responses to the open-ended questions below.

Responses to the three key, open-ended questions were expressed as comments. A thematic analysis of these responses show that, according to the students, the best use of video game technology in their current studies would be broadly across: a) improving learning experiences in general, b) learning structures, c) helping with visualization, d) understanding construction sequencing and processes, e) learning about particular materials and how they are incorporated into a building, and f) the whole issue of thinking in 3D space. The clear majority of responses related to improved learning experience and visualization.

Table 1: Student responses to summary propositions.

#	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Average Score
(i)	14%	6%	24%	43%	14%	3.36
(ii)	1%	2%	28%	54%	15%	3.81
(iii)	1%	8%	49%	36%	5%	3.37
(iv)	0%	5%	21%	61%	13%	3.83
(v)	0%	6%	25%	53%	16%	3.79
(vi)	0%	3%	26%	54%	17%	3.85
(vii)	6%	16%	24%	43%	12%	3.40
(viii)	0%	9%	21%	57%	13%	3.74

There was overwhelming student support for the integration of video game technologies into the curriculum, in equal measure between construction and architecture students. Sixty-four percent of respondents were in favor, 22% expressed some reservations and only 14% believed that further use of video games in the curriculum would be detrimental.

When asked for any comments on the relevance of experience of the construction industry, there were fewer student responses (45). This is most likely because, as first-year students, there would be fewer respondents with industry experience. Sixty-nine percent of respondents identified a positive relevance, primarily for those without previous experience and as the basis for explaining worksite processes and procedures (such as occupational health and safety). Twenty-one percent saw no relevance and 10% qualified their support in terms of the ongoing need for "real" construction site experience as a given.

4 CONCLUSIONS

Situational e-learning involves the use of immersive technologies to provide simulated clinical experiences in circumstances where the provision of actual experiences is prohibited in some way. The most sophisticated immersive technologies today are to be found in video games. The Situation Engine is an application built using a commercial video game development engine, and has been used to provide a stylized construction site where students interact with buildings at various stages of construction to identify the correct construction sequence, along with a range of other forensic and diagnostic tasks.

The development of the Situation Engine and its use within a situational e-learning framework is predicated on a particular approach to learning, termed "situated learning". Situated learning privileges the act of "being" a practitioner and requires the evaluation of any learning technology to be considered in broader terms of context, learner specifics, representation, and pedagogy. This paper reported on a particular evaluation of learner specifics that surveyed 150 undergraduate students in architecture and building, with a 75% plus response rate. Whilst the results are therefore not conclusive, they do represent a significant review of student attitudes to situational e-learning technologies.

The results indicate that in 2012 only just over half (57%) of the participants were already familiar with equivalent video game technologies. However, the pre-mediate experience of the users was generally positive and particularly so in terms of the basic navigation and sense of location within each situation. This positive experience is important, as it could otherwise have had a negative bias on the user attitudes and preferences expressed in response to the propositions that followed. The fact that the pre-mediate experience was generally positive means that the other results are more credible.

There was a very strong balance of agreement (less than 6% overall disagreement) that video game technology is useful to learning in general, specific to design and construction practice, and relevant to the current stage of learning. The attitude of students towards the further development and incorporation of situational e-learning was clearly positive. These quantitative results were borne out by student responses to the three key, open-ended questions, where a thematic analysis showed that only 14% of respondents believed that the use of immersive technologies in the curriculum would be detrimental. Improved learning experiences and visualization capabilities were the potential benefits most often reported.

User preferences were most divided on the issue of situational e-learning as a supplement to actual work experience during the period of study. Fifty-five percent of respondents agreed or strongly agreed with the proposition, but 22% disagreed to some extent. Whilst the average score overall was still positive (at 3.40 on a 1-5 scale), this was one of the lowest scores achieved. It is possible that the disagreement reflected an expressed opinion by 10% of respondents that actual experience of construction should still be a given. In other words, that the potential development of situational e-learning might be being viewed by students as a potential threat to the provision of actual experience. This aspect is a further illustration of how difficult it is to evaluate a situational e-learning technology, as only time will determine if the possibility of a virtual experience will reduce or increase the appetite and need for actual experience.

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