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Using Game Engine Technologies for Increasing Cognitive Stimulation and Perceptive Immersion

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Abstract. *With the development of more user friendly game engine packages and software, detailed cognitive stimulation of procedural activities has now become easier to develop in virtual reality environments. With packages offering built-in visual editors, the amount of labour hours required for the development of specific applications are reduced. This paper considers the use of computer supported game engine technology to provide location independent comprehension and procedural skills learning for built environment education.*

Keywords. Virtual learning, game engine technology, virtual cognitive stimulation and 3D interactivity.

Introduction

There is growing research evidence demonstrating that with the advancement of visualisation and virtual reality environments (VRE), technology based cognitive stimulated learning enhances the user learning experience [1]. Simulation is widely used to support the development of competencies in medical, business and military education. Teaching and training for built environment education (BEE) using computer simulations of buildings although recently developed is not new. In the case of this research the objective is to explore what must be considered to create a Web based cognitive stimulation VRE accessible from desk top personal computers, laptops and hand held devices, to enable individual and group based student learning. The science of learning has established a set of evidence based theories of how people learn grounded in the science of instruction [2]. Established evidence based theories of learning are now recognised as central to the development of learning practice across all fields of learning activity [3]. Computer technology is increasingly using game engine platforms to simulate real life scenarios. The high level of interactivity is promoted through social and work based virtual encounters.

The successful design of any learning programme depends on course material development geared towards the learning experience. The construction industry is a migratory industry in so far as its employees have to migrate long distances to complete various projects. This results in students who have a need for full time employment while studying part time becoming dis-located. Equally the problem

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for full time co-located students is the need to be exposed to real world work practices (through work placement/site visits) before they can begin to form a deep understanding of the built environment discipline/profession. The challenge for BEE is to provide a framework for the delivery of the underpinning knowledge that enables both the co-located and dis-located students to become trained in real world work practices and procedural skills. Equally the challenge for professional higher education teachers, practitioners and computer engineers specialising in computer supported game engine development, is the provision of a platform which enables effective communication of knowledge which can be built with the same proportion of effort as existing computer aided teaching supports.

Technology driven simulated education often runs the risk of been overly bias towards the technology platform. Presently there is limited uptake to incorporate game based VR technology driven simulated education into BEE. What is this reluctance directly a result of? Is it because the technology bias platforms have been known to lend themselves to a negative human educational experience for the users? Evidence from teaching professionals who have engaged with technology driven simulated education such as moodle, blackboard and web CT, in general find the change over from traditional delivery, results in an increased work load. The ongoing management and maintenance of the chosen platforms are time consuming. The National Research Council of Canada [4], Centre for Computer-assisted Construction Technology, carried out an investigation into applying edutainment (game based learning technology) in the construction trades and the use of interactive technology. They presented the observations taken from the developers, teachers and students involved and subsequent conclusions were drawn based on these observations. While this leaning technology is an innovative form for delivering training to students, the students are more comfortable with hands-on learning for a hands-on trade. This study highlighted that technology based learning will only grow as interactive computer technology becomes more accessible. The research concluded that further study is required to find out why the students preferred hands on training.

This paper sets out to investigate (i) the factors influencing BEE, (ii) the need for cognitive stimulation in BEE, (iii) the level of importance at which perceptive immersion is for BEE students, (iv) the success of introducing game engine technology into BEE and (v) the introduction of a concept design framework to develop a VR cognitive stimulation prototype system for BEE. Consideration must also be given to the establishment of a roadmap to help test usability evaluation or human-computer interaction (HCI) [5]. How users and developers view and evaluate simulated interactions is based on an individual's level of knowledge domain and experience in the real world. These differences have a high influence on the success of simulated environments as educational tools [6].

1. Factors influencing BEE

Figure 1 is a summary of the influencing factors affecting BEE and provides focus on the specific knowledge domain of this research. The main research pillars for built environment education (BEE) are;

- didactic of learning,
- style of learning,

- technology spectrum and
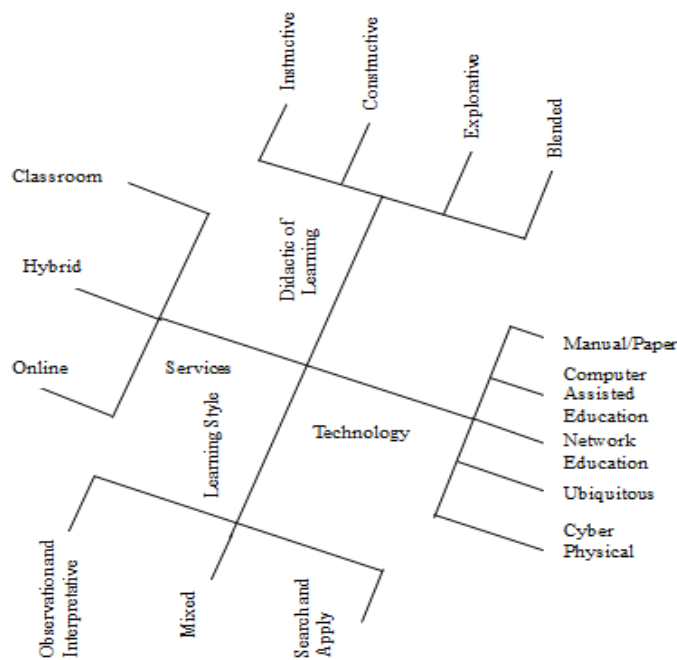- servicing of learning and teaching.

Figure 1. Factors Affecting BEE

1.1. Didactic of learning

The adaptation of the science of learning in its various forms to the task of teaching is evolving in higher education for many years. The established learning theories now provide a learning environment that permits (i) engagement with a subject matter, (ii) allows for individualism, (iii) varied work pace and (iv) provision for student access to course teaching material. Learning and teaching practice provides assessments to test students understanding while at the same time providing guidance for those who fail to meet with the assessment criteria [7]. BEE programmes must recognise and incorporate basic learning theories such as, (i) how people learn [8], (ii) the influence of social interactions [9], (iii) the value of social learning [10] and (iv) the preperation of students to be active participants rather than passive recipients [11].

Instructional process helps to bring about over several successive stages the transformation of information into the learner's long term memory. The purpose of instruction is to arrange external events that will support internal learning. Instructional design must also consider the principles associated with the learning

social-culture aspects and there effect on the selection of educational outcomes. At the outset BEE provide learners with a set of practical steps incorporating the principles of instructional design. Wagner developed the technique of instructional curriculum mapping to integrate intellectual skills with supporting objectives from different domains while Briggs expanded on prescriptions for media based instructional functions [12]. For BEE the learning approach must place an emphasis on the constructivist learning paradigm.

1.2 Style of Learning of BEE students

One of the implications for BEE programmes is that they must prioritise on instruction that builds on student's interests in a collaborative way. BEE programmes need learning activities to be planned by students as well as lecturers, and where student and lecturer not only foster the learning but also learn from their own involvement with each other. The students must be encouraged to construct knowledge in accordance with their own learning style. The use of the cumulative learning theory and a learning hierarchy means that different instructions are required to obtain various learning outcomes. There are a number of learning theories associated with the learning involved in BEE. The theories most associated with BEE are (i) instructional Design, (ii) intelligences (iii) social learning (iv) work based learning and (v) project based learning. Table 1 adapted from a five stage model [13] that support Gagné and Briggs [14] recommendations for designing instruction demonstrates methods for designing BEE instructional teaching.

No.	Recommendation	Clarification
1	Instruction should be planned to facilitate the learning of an individual student	Although students often are grouped for instruction, learning takes place within the individual.
2	Both immediate and long-range phases are included in the design of instruction.	The teacher or instructional designer plans daily lessons, but the lessons occur within the larger segments of units and courses, which also must be planned.
3	The instructional planning should not be haphazard or provide merely a nurturing environment.	Such a course of action can lead to the development of individuals who are not competent.
4	Instructions should be designed using the systems approach.	The systems approach to planning is defined as organized, sequential selection of components that makes use of information, data, and theoretical principles as input at each planning stage.
5	Instructional design should be developed from knowledge about how human beings learn.	

Table 1: Recommendations for designing BEE

The BEE students use a number of intelligences according to the theory of multiple intelligence [8] including but not limited to (i) linguistic, (ii) musical, (iii) bodily/Kinesthetic, (iv) mathematical, (v) spatial, (vi) interpersonal, (viii) intrapersonal and (ix) natural.

The activities of the BEE student are influenced by the environment and the influence of people in varied social settings [15]. Learning normally occurs as a function of the activity, context and culture in which it occurs. Accordingly both co-located and dis-located BEE students are exposed to two different learning situations; on site with an employer and in college with a professional educator and subject matter expert.

Well-structured worked based learning programs and methods of encouraging employer involvement, advances the BEE student learning [16]. The work on site is a reinforcement of the work that is done at the higher education institute. Table 2 illustrates basic design elements that contribute to the quality of a work based learning program [16].

Worked-based Learning program basic design elements	
	Consensus on the work-based program's goals and how to achieve them
	A written learning plan to guide student learning at the workplace
	Work-based experiences designed to help students distil and deepen the lessons of work experience
	Orientation program to prepare students (both socially and psychologically) to enter the workplace
	Worksite learning activities that have been carefully documented and assessed
	Ongoing support and counselling programs to help students cope with the work environment and its demands.

Table 2 Basic design elements of a work based learning programmes

In the absence of employer involvement, project-based learning (PBL) is a good alternative to WBL so long as the BEE student has a major say in the choice of the projects. The projects can focus on the creation of a project or alternatively on a performance. PBL has a (i) time scale and targets, (ii) teacher facilitation, (iii) educational goals, (iv) collaborative learning, (v) reflection and (vi) authentic assessment as the tasks proceed.

1.3 Enabling educational technologies spectrum

There are many software tools used in the construction industry to aid with visual communication. VR 3D game engine software can be manipulated and used to explore 3D visual design options and simulation of the construction process [17]. While there are still many of the emerging 3D interface immersive technologies under development the availability of value for money (i) 2D image editing, (ii) animation, (iii) computer aided design (CAD), (iv) interactive 3D visualization, (v) entertainment, and (vi) games has accelerated in recent years [18]. Computer assisted learning technology is increasingly using game engine platforms to simulate real life scenarios. The high level of interactivity is promoted both through social and work based virtual encounters. The continued development of more user friendly game engine packages and software now means detailed simulated action competencies are becoming a more automated process. Packages offer in-built visual editor's reducing the number of labour hours required.

For example the Unity software which was chosen for the research relating to this paper, provides automated step-by-step and computational power needed to render an animation frame-by-frame. The literature reviewed to date reveals the development of advanced visualisation and virtual environments has the capability to enhance traditional training methods and learner experience. Realistic and relevant virtual

simulation requires careful consideration of numerous and complex behaviours that exist in the real world [19]. With 3D computer animations and a wider choice of VR applications, interactivity and immersions is more readily accessible to the greater BEE population. Before one can meet the challenge of integrating VR technologies, it is imperative that consideration be given to how best these technologies can combine with the learning and teaching methods appropriate to BEE [20].

1.4 Ways of providing services

Providers of higher education are debating key issues which surround the reasons for implementing skills development into their existing programmes. The developed world's future economy is grounded on knowledge. Higher education providers strongly believe that they must change in order to produce a new level of innovative undergraduates [21]. There is now a very strong demand to develop (i) flexible, (ii) innovative and (iii) responsive programmes of BEE incorporating skills development. The development of a knowledge economy requires people to be (i) mobile, (ii) embrace change and (iii) partake in lifelong learning. In recent years, higher education has adopted a more student or learner centred approach moving away from traditional lecture centred delivery [22].

Modern educationalists are beginning to agree more and more that acquiring knowledge through formal or informal education and training are equally acceptable forms of knowledge gain [23]. The VR learning environment element of any learning programme offers a different experience from classroom-based learning. The learning pedagogical support needs to ensure the cognitive stimulation and perceptive immersion is created. The challenge for professional higher education teachers, practitioners and computer engineers is the provision of a platform which enables effective communication of knowledge and reduces the barrier to entry. The design and delivery of a virtual reality interactive learning simulator for BEE, places an emphasis on ensuring students understand that the knowledge has an application to a real-life scenario. The aim of effective education strategies is to bring about the conditions under which meaningful knowledge transfer can take place.

2. The need for cognitive stimulation in BEE

Cognitive stimulation is defined as promotion of awareness and comprehension of surroundings and is knowledge referred to as cognitive development learned through mental processes and sensory perceptions [24]. The five sensory modes are (i) seeing, (ii) hearing, (iii) touching, (iv) tasting, and (v) smelling, three of which (seeing, hearing, and touching) are required for maximum development of the mental or cognitive BEE processes. BEE students depend on the ability to recognise the environment in 3 dimensional views [25]. The growth in popularity of 3D drawing packages and walk through virtual environments for visual design, provide a rich interactive educational context which supports BEE [26]. The result of how effective these supports are for the BEE student's learning experience is determined by improved performance and is a measure of the potential for future learning success.

There is growing research evidence demonstrating that the advancement of visualisation and virtual reality environments can enhance the BEE student learning experience [27]. A future scope of this research will consider if the development of

advanced visualisation and virtual environments can enhance traditional training methods and learner experience. The technology tools are intended to provide the students the opportunity to create their understanding and to construct their own interpretations against a backdrop of shared understanding, practices, language and so forth [28].

3. The level of importance at which perceptive immersion is for BEE students,

As stated earlier both co-located and dislocated BEE students have a need to be exposed to work and classroom practice. The process of design and construction undergoes incremental development with some changes made during the process, as result of visualisation and insightful gains [29]. Architecture, engineering and construction (AEC) industry requires collaboration when it comes to designing a building or other such projects, in order to ensure a shared understanding between all stakeholders is achieved. It is because of this, that makes it all the more important for BEE students to have an opportunity to learn through observation and experiment with the construction process of varied project types [30]. The advances in CAD technology from 2D, 3D, 4D and now it's compatibility with VR game software, has provided the opportunity for students to experiment with varied construction process scenario's.

Figure 2 is adapted from the work of Graff [31] and highlights the key recommendations for design of Virtual learning Environments (VLEs). Like most systems, the technical requirements are software and hardware based but then link into the requirements of teaching, such as (i) simple active linear text, (ii) general vision maps, (iii) videos, (iv) animations, (v) chat, (vi) forum and (vii) navigation. Game engine technology will allow synchronous, or real-time, communication to take place such as a conference call (often referred to as voice chat). Real time communication is important for the teacher-user to communicate but equally it becomes an important student-user function for effective two way communication, eliminating the need for either user to learn a new skill such as, typing. Asynchronous, takes place outside of real-time, it is of concern for both teaching and pedagogic content. The users are very concerned with ability of the system to be user friendly from their perspective.

In a similar way to the application of information and communication technologies (ICT) to VLEs, the development and adaptation of VR with VLEs give the learner the perception of presence regardless of the type of environment, (i) classroom, (ii) a laboratory or (iii) a workshop. This is known as immersive learning and when combined with novelty and innovation using both VR and Augmented Reality (AR) common to game engine software, the experience for the user is further enhanced to create a perceived immersed learning experience.
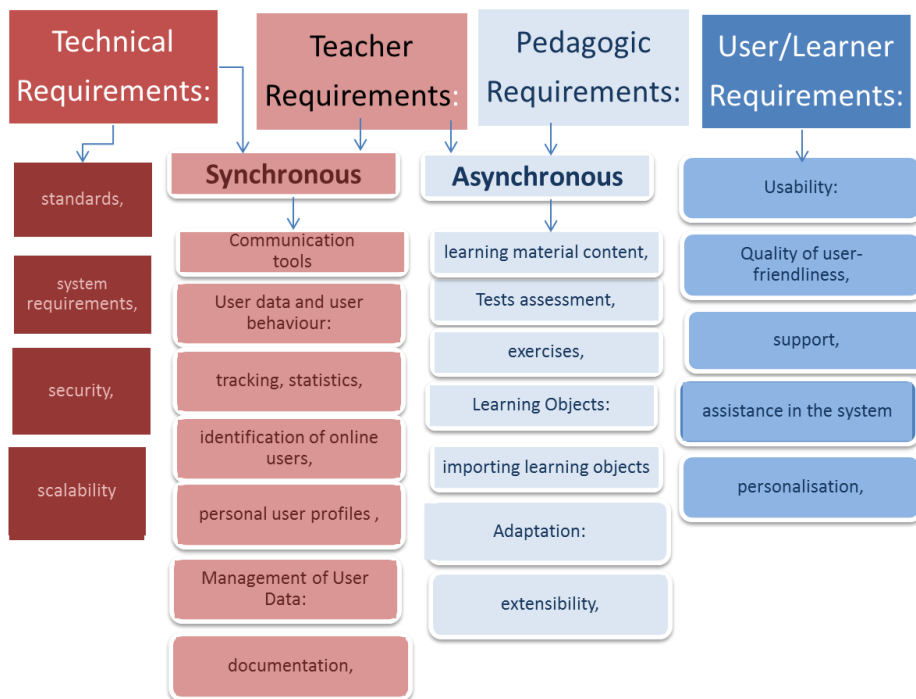
Figure 2: Recommendations for design of virtual learning environment Graff (2007)

4. The success of introducing game engine technology into BEE

Advanced visualisation and virtual environments are not yet common place in favour of presentation using visual aids such as power point, smart board and projector technology in BEE. Literature reviewed to date reveals a small number of studies on the application of 3D interactive VR for BEE [33]. The main focus of these studies relates to application of VR for BEE and tends to lean toward proof of concept testing and feasibility. The evidence suggests the success of concept and feasibility, results in a positive outcome when both the developer and user have a high understanding of the rationale and context in which the VR environment has been developed. How users and developers view and evaluate VR interactions is based on an individual's level of knowledge domain and experience in the real world. These differences have a high influence on the success of VR environments as educational tools [34].

AEC industry experts increasingly rely upon modern technologies to meet the demands of today's complex projects. Computer engineering researchers have developed intelligent VR environments that animate AEC operations and processes [35]. Development and testing of a concept theory for enhancing expertise through VLEs and enabling its ease of integration into every day BEE teaching practice requires further investigation. Building Information Modelling (BIM) has increased in popularity in recent years because of its ability to produce interactive models which are more intuitive and appealing to decision makers. One obvious advantage of using BIM software is its ability to replace the need to use traditional 2D detailed multiple

architectural drawings layout in an open plan site office. 3D models of each construction item are developed and imported into a VR environment which can be easily manipulated to resolve potential real world conflict and clashes. The evolution of VR technology and its manifestation in AEC practice is self-evident in recent UK Government public tendering legislation for the AEC industry.

5. The introduction of a concept design framework to develop a VR cognitive stimulation prototype system for BEE.

Figure 3, illustrates the workflow in the building of a 3D model for the Virtual Reality Stimulation Prototype, (VRSP). This is developed through a number of platforms before being imported into game engine software. The first step in building the testable VRSP was the recreation of mechanical refrigeration training equipment based on the real life model in the depicted in figure 3(A). The virtual 3D objects duplicate the functionality of the specialist procedural competencies training laboratory. The objects were built using standard modelling approaches from mesh to textured and rendered mesh. Figure 3(B) shows the model in place in the game engine software and ready for introduction of user interaction.

The evidence uncovered in the literature feedback tends to indicate the additional supports that are required for VR cognitive stimulated online procedural task learning are:

- The VR file size needs to be compatible with the internet connection source to ensure students gain access online quickly and easily.
- Delivery of content needs to be engaging, thereby motivating and encouraging students to spend quality time online and to return willingly over the course of the module.
- Simple to use model library resources provides students with virtual building blocks motivating them to take charge of their learning.
- The VRSP design needs to be compatible with mobile devices to help students expand their learning environment into their world of social networking.

6. Conclusions

The use of game engine technology for increasing cognitive stimulation and perceptive immersive learning requires the careful design of a BEE framework which incorporates supporting technologies that enable procedural VR perceptive learning. Development enhancement of the technologies requires further investigation into the user (teacher and student) requirements. There are promising technologies but the complexity of development for the novice teacher-user and student-user to meet the basic functionality of procedural competencies still require further investigations and research experiments.

Interactive 3D computer games have been applied in developing VLEs at the expense of developing learning concepts for VLEs [32]. In order to achieve better results, advanced 3D technologies need to be used in conjunction with a theoretical framework for pedagogy. At present research for VLEs is very much focussed on application of

software and hardware. There is a need to focus research on identifying real life working scenarios from architectural, engineering and construction and simulate these as immersive perceptive learning and teaching environments.
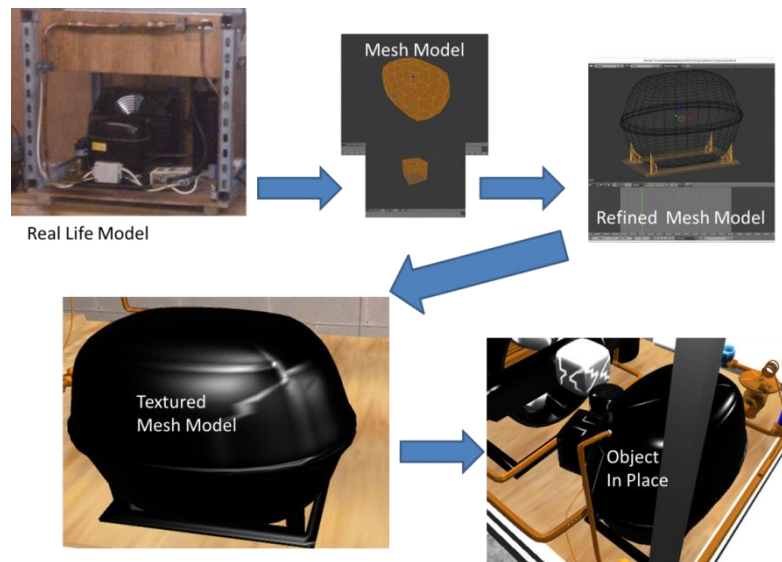
(A) Workflow - Sample of Construction for 3D Models
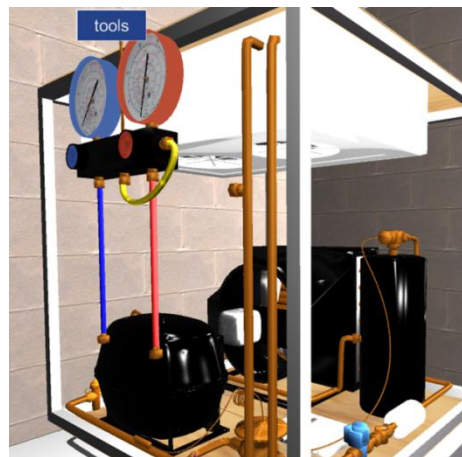
(B) Object in Place in Game Engine

Figure 3: Model Workflow and Game Engine Interaction

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