VIRTUAL WORLDS AS A CONSTRUCTIVIST LEARNING PLATFORM: EVALUATIONS OF 3D VIRTUAL WORLDS ON DESIGN TEACHING AND LEARNING

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SUMMARY: *With the recent developments in information and communication technologies, 3D virtual worlds have the potential to make a major contribution to design education as a constructivist learning environment. Considering the changing trend in design education, we have been employing virtual world technologies in our design teaching, allowing students to collaborate within the 3D virtual environments such as Second Life (www.secondlife.com) and Active Worlds (www.activeworlds.com), which support synchronized design communication and real-time 3D modeling. This paper reports our teaching experience and the students' learning experience, based on team-based design and communication skills-building in 3D virtual worlds and presents the challenges faced by design education when utilizing such environments. In this paper, we firstly provide a critical analysis of various design learning and teaching features in 3D virtual environments as constructivist learning environments, and secondly consider the core skills and cognitive processes involved when designing and learning in 3D virtual worlds.*

KEYWORDS: *Constructivist learning, 3D virtual worlds, design teaching and learning, affordances and constraints.*

1. INTRODUCTION

Design education is concerned with teaching theory and applications in the design of artifacts that could occupy human activities. Historically, schools of architecture taught "descriptive geometry" (Lee and Reekie, 1949), based on a Euclidean understanding of form and space. The revolution of the paper technology in the fifteenth century can be considered as the "application" that enabled "the intellectualization of buildings", leading the notion of architecture as we know it today (Kvan et al., 2004). As an ongoing process, today the communication and information technologies bring new challenges for design education that require the consideration of new pedagogical approaches employing emerging design medium (Gu et al., 2007). Innovative approaches to design education should include in the curriculum the demonstration of the impact of computer technologies have in creating "new ways of designing" (Kvan et al., 2004) integrating the teaching of digital skills (craft) and design thinking (art) (Gül et al., 2007, Kvan et al., 2004).

In relation to this view, 3D virtual worlds offer many opportunities for design teaching and learning. There are approaches which integrate the emerging fields of digital design into design education, such as employing parametric design, interaction design, experience design, graphic design, product design, etc. Although these studies employ new technologies into design education, there is still a general lack of research and practice which explores the potential of design teaching in 3D virtual worlds as a constructivist learning platform. Perkins (1991) classified constructivist paraphernalia including information banks, symbol pads, construction kits, phenomenaria and task managers. According to Perkins, computational tools facilitate human memory and intelligence to interpret experience and to refine mental models. Thus computer-supported constructivist learning environments focus on how representations and applications can mediate interactions among learners and natural or social phenomena (Dede, 1995).

In considering these changing trends in design education, we have been employing virtual world technologies in our design teaching, allowing students to design and collaborate within 3D virtual worlds including Second Life (SL) (www.secondlife.com) and Active Worlds (AW) (www.activeworlds.com). These environments support synchronized design communication and real-time 3D modeling. This paper reports our teaching experience and the students' learning experience, based on team-based design and communication skills-building in 3D virtual worlds and presents the challenges faced by design education today. The paper firstly provides a critical analysis of various design learning and teaching features in 3D virtual worlds as constructivist learning environments, and secondly identifies a number of key issues in addressing the core skills and cognitive processes of designing in 3D virtual worlds.

2. VIRTUAL WORLDS AS CONSTRUCTIVIST LEARNING ENVIRONMENTS FOR DESIGN EDUCATION

Broadly, the educational approaches for various design disciplines fall into three groups: those evolving from a fine-arts background and generally conforming to a studio-based Beaux Artes educational model; those evolving from a technology background and generally conforming to an applied science educational model; and those who have sought alternative approaches, generally being combinations of Beaux Artes and scientific models.

Interest in alternative educational approaches to design education has been gradually increasing since the Bauhaus experiments of the 1930s in Germany and their "migration" to America in the post-war years and then to design education institutions throughout the developed world. The "Reflective Practitioner" philosophy of Donald Schön [1983] of the University of Wisconsin (Milwaukee, USA), focused particularly on architectural and engineering education, was developed from Bauhaus principles and led initially to the introduction of "Problem-Based Learning" by Donald Woods (1985) of McMaster University (Hamilton, Ontario, Canada) for undergraduate engineering design education. Woods' approach was a form of experiential learning focused on integration of diverse knowledge and skills, and problem-solving praxis to meet "real world" relevance expected by employers, all brought together through reflection.

A variation on a combination of Schön's and Woods' themes was a "cognitive apprentice" model (also called "Problem-Based Learning") developed by Howard Barrows (1986)' for medical education. This, in turn, was further adapted to architectural and other design education domains, including particularly a "Block" model in architecture and related design programmes at TUDelft (de Graff & Westrik, 1994), Netherlands and an "Integrated Learning" model and a "Research-Based Learning" model in architecture at the University of Newcastle (Maitland, 1985), Australia. The outstanding success and acceptance of Woods', Schön's, Barrows', Delft's and Newcastle's models led to further adaptations across a wide range of design education disciplines.

Many design educators reacted against these innovations and entrenched themselves in "scientific" design education approaches based on rigorous analytical design routines. A majority, however, adopted various combinations of scientific and studio-based approaches, with studio-based tutorials and master classes for some parts of their programmes, and analytical, procedural approaches for the other parts, often using parts of Schön's and Woods' theories to justify existing conventional studio-based tutorial and master-class design teaching practices.

As an ongoing process, constructivism can be employed as a design teaching approach which includes the facilitation of the emerging information and communication technologies. Constructivism characterizes how individuals construct their own understanding and knowledge of the world, through experiencing things and reflecting on those experiences (Mahoney, 2004, Huitt, 2003). According to the constructivist view, the learning process involves the followings: knowledge is obtained and understanding is expanded through active (re)constructions of mental frameworks (Piaget through to Abbott & Ryan, 1999; Bransford, Brown & Cocking, 2000), and learning is an active process involving deliberate progressive construction and deepening of meaning (Spady, 2001). An awareness of these patterns helps to anticipate and respond to students' understandings (Brooks and Brooks, 1999).

Cognitive constructivism – focusing on the cognitive processes people use to make sense of the world (Berk, 1997; Riegler, 2005), and social constructivism – focusing on learning as a social process wherein students acquire knowledge through proactive interaction with significant others (Snowman and Biehler, 2000) both primarily impact the 'competent, creative, mindful, collaborative and constructive dimensions' of learning (Spady, 2001). The social version of constructivism emphasizes how students can gain new strategies through peer collaboration by interpersonal discourse (Forman and Cazden, 1985). The influential psychologists Bruner (1966) makes the case for education as a knowledge-getting process:

"To instruct someone... is not a matter of getting him to commit results to mind. Rather, it is to teach him to participate in the process that makes possible the establishment of knowledge. We teach a subject not to produce little living libraries on that subject, but rather to get a student to think mathematically for her/himself, to consider matters as an historian does, to take part in the process of knowledge-getting. Knowing is a process not a product" (1966: 72) (as cited in Smith, 2002).

This approach to teaching and learning takes place in problem-solving situations and the constructive learning is considered essential in effective design education.

2.1 Approaches to constructing knowledge in computer-supported education

Winn (1993) identified four different approaches in educational computing. The first one is based on behavior theory that gave rise to traditional approaches to instructional design (Dick and Carey, 1985, Gagne et al., 1988) that includes:

1. Predicting students' behavior (Reigeluth, 1983),
2. Reducing necessary knowledge and skills by using appropriate analytical techniques (Landa, 1983), and
3. Following a set of procedures to ensure that instruction developed by their systematic application will work effectively without further intervention from designers or teachers (Winn, 1993).

The second approach is based on how information is presented to students (Fleming and Levie, 1993). The emphasis in this approach is on how students process information and has a greater impact on what they have learned rather than on the accuracy of task reduction and prescription of instructional strategies on the basis of content (Winn, 1993). Psychologists realize that cognitive theories of learning and instruction provide a sources for instructional designers to draw upon for guidance rather than behavioral theory (Winn, 1993).

The third approach which is based on cognitive theories arose from the belief that the nature of the interaction between the students and instruction is a determinant of learning equal to, if not of greater importance than content or how information is presented (Winn, 1993). For example, Anderson's ACT* cognitive theory (Anderson, 1983, Anderson, 1976) formed the basis of 'intelligent' computer-based tutors which included the following principals:

1. Identifying the goal structure of the problem space,
2. Providing instruction in the context of problem-solving,
3. Providing immediate feedback on errors,
4. Minimizing working memory load,
5. Adjusting the "grain size" of instruction with learning to account for the knowledge compilation process, and
6. Enabling the student to approach the target skill by successive approximation.

The fourth approach relies on an understanding of how students interact with courseware, the assumption is that, knowledge is constructed by the students themselves, not through the delivered of the courseware (Winn, 1993). In this constructivist view, the knowledge is constructed, not transmitted and the students actively learn (Jonassen, 1999). To enhance learning, students should be given opportunity for exploration and manipulation within the environment as well as opportunities for discourse between students (Dickey, 2007). Within this content, students have opportunity to apply new knowledge and skills in a collaborative shared environment (Gül et al., 2007). In learning as constructivist activity, the role of teachers is “to help and guide the student in the conceptual organization of certain areas of experience” (Glasersfeld, 1983).

In our development of designing and applying 3D virtual worlds in design education, we maintain the last two approaches of Winn’s to emphasize the use of 3D virtual worlds as design and learning environments, providing structured tutorials, immediate feedbacks and the opportunities to interact within the environments. 3D virtual worlds distinguish themselves from other networked technologies by having place characteristics (the use of place metaphor in designing and constructing 3D virtual worlds). 3D virtual worlds are not just another medium of communication but rather the ultimate “world” where we shop, are entertained and get educated (Kalay and Marx, 2001). Although virtual worlds have gradually become an important part of the holistic environment we inhabit, most often design schools have not recognized designing in virtual worlds as a design subject, rather the current focus is on the technical aspects as a Computer-aided Design (CAD) tool for design simulation and remote team collaboration. Thus the consideration of the aspects of 3D virtual worlds for designing and collaboration is essential in the course development.

2.2 Design learning and engagement in virtual worlds

Integration of communication and information technologies into design curricula offers significant potentials for design schools, through their capacity to facilitate designing in new learning environments, advancing research and development in learning theories. There are approaches which employ these emerging fields of digital design into design educations including employing parametric design, interaction design, experience design, graphic design, product design, etc. Our research distinguishes from these studies by exploring the potential of 3D virtual worlds as constructivist learning environments in design education. Further, we teach subjects that regard 3D virtual worlds as a design discipline in its own right.

Research of educational use of Virtual Reality (VR) provides compelling evidence of the potential of the emerging 3D virtual worlds to facilitate constructivist learning activities (Dede et al., 1996, Dede, 1995, Winn, 1993). One of the main advantages of VR identified is that students are able to view an object or setting from multiple perspectives (Dede, 1995). Dede (1995) points out that virtual environments offer many benefits including opportunities for experimentation without real-world repercussions, opportunities to ‘learn by doing’, or ‘experiential learning’ and ability to personalize an environment. From the mid 1990s, virtual design studios (Kahneman and Tversky, 1996, Kvan et al., 2000, Maher, 1999, Schnabel et al., 2001) have been established in architecture and design schools internationally. These virtual design studios aim to provide a shared “place” where distant design collaboration can take place especially synchronized communications and design activities. The forms of virtual design studios vary from the early approach of digital design data sharing to the more recent 3D virtual world approach where the designs as well as the designers and the learners, are simulated and represented in the virtual worlds allowing "design and learning within the design". This new phenomenon has caught the attention of many design academics. Kvan (2001) argues that while design education has traditionally focused on the product, virtual design studios allow students to learn more about the design process. Dickey (2005) suggests 3D virtual worlds can provide "experiential" and "situated" learning. Clark and Maher (2005) examine the role of place in virtual learning environments which encourages "collaboration and constructivism". Wyeld et al. (2006) identified the potential of the use of virtual learning environments in supporting social awareness among design students focusing on the cultural aspect in virtual learning environments where students from different cultural backgrounds design collaboratively.

2.3 Virtual worlds design

Today the communication and information technologies bring new challenges and opportunities to design education which require the consideration of new pedagogical approaches when employing emerging design fields. An innovative approach to design education should include a demonstration of the impact of computer technologies on "new ways of designing" (Kvan et al., 2004) integrating the teaching of digital skills (craft) and the concept of design thinking (art). In relation to this view, the emerging field of 3D virtual worlds offers many opportunities for design teaching that requires understanding the principles of virtual worlds design.

Virtual worlds design and architectural design: The early development of 3D virtual worlds has been closely related to architectural design due to its use of the "place" metaphor. Through this metaphor, virtual worlds can inherit many of the characteristics from architecture. Massively Multiplayer Online Real Life Games (MMORLGs) as well as those examples which have the sole purposes of simulation such as virtual heritage worlds and military simulation worlds only mimic the physical world. As a result, the focus of these designs has been placed on VR and social aspects in order to make the virtual environments as close to their physical counterparts as possible.

Virtual worlds design and interaction design: Designing in virtual worlds can go beyond imitating the physical world yet still focuses on accommodating human activities, in particular, interactions that are not readily available in the physical environments. The examples of virtual world design as interaction design include the largely popular interactive online games and the recently emerging agent-based intelligent worlds. Situated in such an environment, a software agent is capable of reasoning about the world and acting upon its beliefs and desires (Wooldridge, 2000). Mediated with software agents, 3D virtual worlds become intelligent networked environments. Smith et al. (2003) develop 3D virtual worlds that respond to their inhabitants in reflective, reactive and even proactive modes. This is achieved by applying a multi-agent model which enables each component in the virtual world to be an agent. Using a design agent model, Gu and Maher (2005) develop dynamic 3D virtual worlds that are designed and modified as needed during use.

Designing within the design: Maher and Simoff (2000) first characterize the design activities in 3D virtual worlds as "Designing within the Design". Unlike in the general CAD systems designers in virtual worlds are represented as avatars (animated virtual characters) that are immersed within the design. This concept has also been studied to enhance remote team collaboration in design practice (Rosenman et al., 2005). 3D virtual worlds provide an integral platform that utilizes team collaboration, design representation, modeling and in the case of designing virtual worlds, even design realization.

3. THE "DESIGNING VIRTUAL WORLDS" COURSE

In support of the intention of employing virtual worlds as constructivist learning environments, we develop the "Design Virtual World" course. "Designing Virtual Worlds" was offered as a full-semester (13 weeks) unit. The weekly schedule includes a 1-hour lecture and a 2-hour design studio.

As discussed earlier, although virtual worlds have gradually become an important part of the holistic environment we inhabit, often design schools have not recognized designing in virtual worlds as a core design subject. The current focus is on the technical aspects of virtual worlds as a CAD tool for design simulation and remote team collaboration. "Design Virtual Worlds" therefore also goes beyond these traditional uses to rather regard 3D virtual worlds as a design discipline in its own right. The course attracted 20 postgraduate students from the disciplines of architecture, engineering, design computing and digital media, and involved them in exploring interesting ideas and new possibilities for designing 3D virtual worlds.

Course objectives and structure: the objectives of this subject were for students to:

1. Develop an understanding of the 3D virtual world as a new kind of environment design,
2. Gain knowledge and hands-on experience in design and implementation of virtual worlds, and
3. Explore the use of 3D virtual worlds as constructivist learning platforms for design education.

The course content was structured so that students would gain an understanding of the environment and the skills necessary for designing in 3D virtual worlds. For the students to develop their understanding of virtual worlds, firstly, they were asked to consult relevant literature. Design examples were then introduced and discussed through lectures and group discussions. Secondly, students were instructed to inhabit and critically assess a wide variety of virtual worlds reporting their experiences in a short essay which involved them reflecting on their learning outcomes. In order for the students to gain adequate design knowledge and technical implementation skills, two design projects were scheduled as major submissions for the course.

Design projects: With structured design supervision and technical tutorials, the two design projects which are one individual and one group projects, provided opportunities for students to:

1. Develop and apply design principles of 3D virtual worlds,
2. Master the knowledge and techniques for virtual world implementation, and
3. Exercise individual design and group collaboration skills.

In the individual project, each student designed and implemented a personal virtual gallery for displaying her/his digital design portfolio. The whole class was then divided into four groups. Each group designed and implemented a virtual place. Through interactions between the avatars and the designed place, the group's understanding of "virtual experience" would need to be demonstrated. The virtual place and the virtual experience were recorded on a digital video.

The group project exercised all required skills for designing 3D virtual worlds. These included architecture-related skills (place design), digital design skills (modeling, imaging, video and audio production, scripting and programming), communication and collaboration skills and generic design skills (problem-solving). In the group project, students from different backgrounds were grouped together allowing them the opportunity to work on their own interest and with their particular expertise but still within the collaborative environment. For assessment, multi-dimensional criteria were applied to cover the different design and technical aspects and jury members were invited from the areas of architecture, interaction and game design, and computer programming providing students with feedbacks drawn from the different perspectives.

Compared to other approaches where 3D virtual worlds are used as a technical tool for CAD modeling or distant learning, this approach regards 3D virtual worlds as a design discipline which adds new dimensions to 3D virtual worlds. These dimensions include the consideration of interaction design, metaphorical/virtual design and experience design other than only mimicking the physical world. 3D virtual worlds as a design subject will prepare future generations of designers to develop an understanding of 3D virtual worlds as a new design environment which will become an important part of our holistic living environment. The emergence and further integration of this subject with the current teaching curriculum will provide new opportunities and challenges for architecture and design education, such as utilizing virtual worlds as new design platforms.

4. EVALUATIONS OF 3D VIRTUAL WORLDS AS CONSTRUCTIVIST LEARNING ENVIRONMENTS

Most 3D virtual worlds offer constructivist learning environments and can enhance learning by: providing opportunities for exploration and manipulation in the virtual environments, providing opportunities for discourse between students and other users' of the environment as well as providing opportunities to actively build skills and knowledge in relation to their interest. In our course development of "Designing 3D Virtual Worlds", we maintain the last two approaches of Winn's to emphasize the use of 3D virtual worlds as design and learning environments, providing structured tutorials, immediate feedbacks and the opportunities to interact within the environments.

In the following section, we discuss (1) design features of 3D virtual worlds and 3D virtual worlds as constructivist learning environments and (2) two aspects of human behavior that are core skills and cognitive behavior in the two of the most popular 3D virtual world platforms: Active Worlds (AW) and Second Life (SL).

4.1 Evaluations of design features in 3D virtual worlds

The approach for the evaluations of design features in 3D virtual worlds is drawn from Dickey's (2007). In his study, Dickey (2007) points out that affordance theory has relevance when examining learning environments. In the context of constructivist concept, the affordances and constraints of the learning environments affect the opportunities for construction (Dickey, 2007).

Affordances theory was developed by Gibson (1977) who suggested that humans "perceive" in order to operate on the environment. Perception is designed for action that is called 'the perceivable possibilities for action affordances'. He claimed that people perceive affordance properties of the environment in a direct and immediate way, i.e. surfaces for walking, handles for pulling, space for navigation, tools for manipulating, etc. (Norman, 1988). Gül (2008) points out that different virtual environments provide different affordances which have an impact on user's behavior. Within this framework and based on our observations and discussions with the students during the lectures and design studios, we identified the affordances and constraints of AW and SL, these are outlined below.

3D modeling features

Affordance: Both 3D virtual worlds support different view points which are first-person view and third-person view. 3D virtual worlds offer many possibilities for understanding the spatial arrangement of the objects and developing student's spatial abilities. AW supports the so-called library-based design method which comprises a set of objects whose forms are pre-defined outside the world and provided by the object library of the design platform. To modify the forms beyond standard library objects requires object library updates. FIG 1a shows one of the student designs which required several library updates. Each piece of the model is uploaded separately, and then assembled in AW. Also discovered when using library-based designs, students with less modeling experience could rely heavily on the use of standard library objects provided by AW. FIG 1b demonstrates designing using AW standard library objects. As a result, the affordances of library-based designs provide the uniformed "AW look" due to the repetitive use of standard library objects, as shown in FIG. 1b.

SL supports the parametric design method which comprises a set of objects whose forms are determined inside the world by selecting geometric types and manipulating their parameters. They can also be freely adjusted within the world at a later stage. Design platforms that support the parametric design method are therefore modeling tools as well. The affordance of SL encourages students to generate models that look unique. FIG. 2 shows two students examples in SL: the virtual big brother and virtual idol projects. Each object is modeled by the students starting with a primitive.

Constraints: The approaches to generating customized models in AW can be cumbersome as users are unable to model directly. To create a customized model firstly requires using a CAD or a modeling application, and then converting the model into ‘rwx’ file format with the consideration of the scale, texture, positioning in AW[1]. The “rwx” file is a text file that can be edited with any text editor. They define the shape of an object in AW. It is also important to consider how to separate the model into different objects as behaviors in AW can only be applied to a selectable object but not a part of the model. For example, if a model as a whole is to be used in AW, actions can only apply to the whole model. If each component is to have its own behaviors, it is a requirement to have a separated model and to export different parts of this model individually. They can then be located and combined together as a whole in AW. FIG. 1a show a customized object designed by a student who adopt the approach described above.

Another approach to generate customized models for AW is to modify existing files using the ‘Alpha World Building Objects’ library then using operations to rotate, scale, and change color or texture. The first step is to download an existing model that you want to modify, and then open the ‘rwx’ file to make any necessary modifications, and upload the modified file to the AW server to be used for design.

SL, on the other hand, provides a platform where students can start designing from the early stage using basic geometric forms. However, this can be a challenge for some students who were novice designers. Some students commented that they had to sketch their design ideas on paper in order to understand the overall design layout, prior to modelling the design in SL.

Collaborative design and workspace awareness

Affordance: Most virtual worlds support synchronous communication and collaboration including AW and SL. Both virtual worlds have a text-based communication features. Users can communicate by typing in the chat dialogue box in AW. In SL, similar to AW, the texts appear above the avatars’ heads. FIG. 3 shows the chat dialog box and avatar’s text boxes above their heads. Both AW and SL afford the presence of designers/learners and their collaborators (awareness of self and others), use of place metaphor (awareness of the place); navigation and orientation (way finding aids).

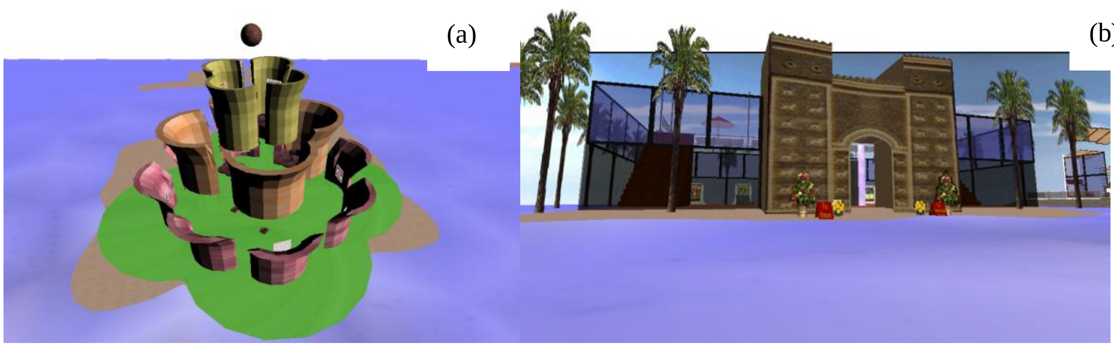

FIG. 1: Student designs in AW, a) a customized model uploaded to the server, b) a model using standard library objects

[1] The RWX format was once used by RenderWare as the native 3D model format. (see http://www.activeworlds.com/help/aw41/document.php?rwx_overview for more details).

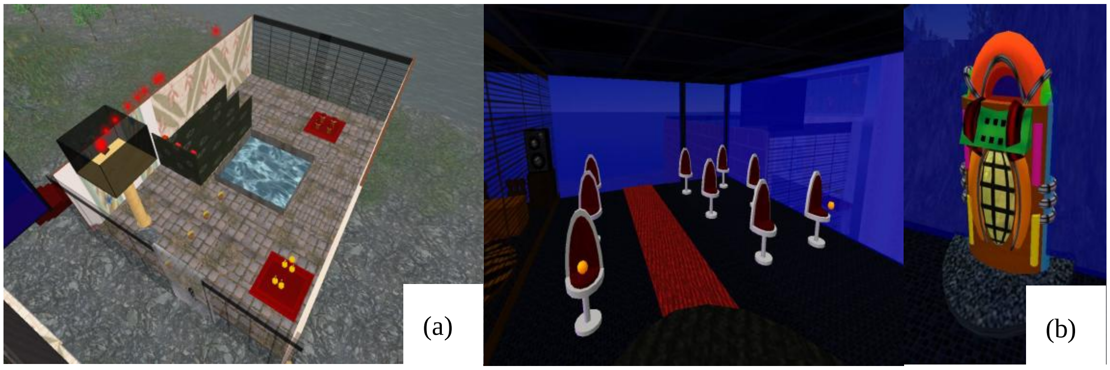

FIG. 2: Students designs in SL, a) Virtual Big Brother house, b)Virtual Idol venue

In AW, users may only manipulate (move/rotate/change/transform) the properties of their own object. In the group project, we observed that the affordances of ownership of the objects require a structured-task division while designing collaboratively. This means that students need to determine the overall concept of the design and separate the parts to construct the model. In SL, the ownership of the objects can be flexibly arranged and shared, but one user only can manipulate an object's properties/location at a time. Thus these features of the 3D modeling environments might encourage the designers to work individually on separate parts of the design model in a collaborative task.

Constraints: AW allows individuals to move freely around the 3D workspace while still providing information about the shared design representation and the position of the others (via the presence of the avatars) however the technique of manipulating the design objects does not support workspace awareness. In AW, students are only able to see the results of other's modeling actions but not the actual modeling actions and processes. Therefore monitoring collaboration and coordinating each other's actions become a difficult issue.

In contrast, SL, provides more workspace awareness through 'consequential communication' and 'feed-through'. In consequential communication, the characteristic movements of an action (for example typing includes hand movements or walking includes legs and body) communicate its character and content to others (Segal, 1995). In feed-through, the feedback produced when objects are manipulated provides others with clues about the manipulations (Dix et al., 1993). For example, in SL, when a student is modeling/manipulating an object, a light blob that shows a link between the avatar and the object will appear, and when the student communicate using the keyboard, the avatar also appears to be typing in the virtual world. This feature supports workspace awareness through 'consequential communication'. In addition, in SL, when a student is transferring or moving an object, these manipulations are visible to others. This is an example of 'feed-through' behaviors that support workspace awareness. Due to these features of SL, the students are aware of each other's actions and can focus more on the development of the design model in a collaborative design task.

In both platforms, it is important to moderate the discussion in a large class as multiple trends often emerge during online discussion which can easily lose the topic focus if without adequate moderation.

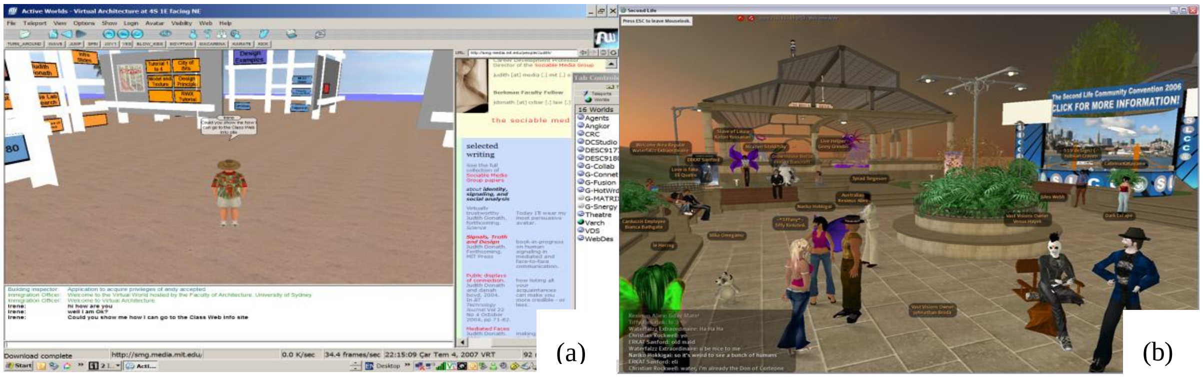

FIG. 3: Screen shots: a) AW showing the chat box at the bottom of the window and the text balloon above the head of an avatar, b)SL showing text balloons above the heads of the avatars and the list of messages on the bottom left of the window.

Scripting/programming for interactivity

Affordance: Both AW and SL enable in-world scripting to support interactions in the virtual environments. AW provides a library of scripts for common interactions such as creating a hyperlink, teleporting, object animation and so on. Users can easily implement simple interactions using this library of existing scripts. SL scripting is more robust, as it supports a scripting language called LSL[2] (Linden Script Language), a programming language similar to Java.

Constraints: Although creating common interactions is simple in AW due to the library of implemented scripts. It does not support advanced interactions other than the standard ones supported by the library. The robust scripting environments in SL on the other hand does support advanced interactions. However it is very difficult to be mastered by designers without a computing background. FIG. 4 shows two students examples in SL and AW. In SL a group of students designed a five-storey gaming building providing different gaming experiences. Each floor has different types of interactions, for example, escaping from pop-up-obstacles and blades, and guessing games by choosing from black and white boxes, as shown in FIG. 4a. In AW, a student designed a virtual gallery that become visible when the avatars visit each interactive place that responds to the presence of avatars during their visits, as illustrated in FIG. 4b.

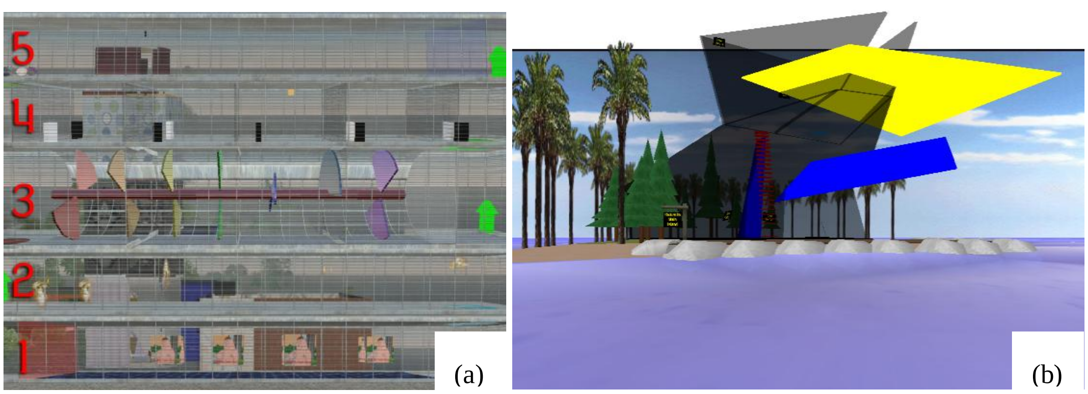

FIG. 4: Providing interactivity. (a) the façade of a virtual gaming building in SL, (b) an exploration of interactive place in AW.

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[2] See http://wiki.secondlife.com/wiki/LSL_Portal for more details on LSL.

4.2 Evaluations of human behavior in 3D virtual worlds

Teaching in virtual worlds requires the understanding of human behavior, in particular understanding the key aspects of human communication and cognitive processes are essential.

Core skills for teamwork in 3D virtual worlds: The core skills are essential for design collaboration in 3D virtual worlds; therefore they are important for students to master and should be embedded in courses taught in 3D virtual worlds. Bellamy et al. (2005) identified the following core skills for designers effectively participate in collaborative design:

- Leadership is important because it decides the balance of relevant skills and contributions required from team members. Team leader(s) need to be able to create teams that identify the important "social links" between team members (Baird et al., 2000).
- Co-ordination and structuring skills are required for team members to work collaboratively in a virtual environment (Lahti et al., 2004).
- Feedback abilities are also important skills for team members. This is crucial because large amounts of information often need to be validated in virtual worlds (Baird et al, 2000).
- Interpersonal relationships between virtual team members can impact on the team's ability to provide a satisfactory product. In addition, social collaboration appears to play an important part especially when researching and determining limitations.
- Trust is not easily created in a computer-mediated environment including 3D virtual worlds, especially when team members have no prior experience. The commitment of others fosters trust, but this trust may not reach its highest level until the end of a task (Jarvenpaa and Liedner, 1998).

We also experienced the above issues in delivering these initiatives. One of the objectives of the subject was to exercise group collaborations skills. Based on students' previous design experience and programming/scripting skills, five groups were formed. Since the main consideration of forming the groups was the students' background, trust and shared understanding of the design context took some time to establish between group members. In our experience, we require the groups to submit weekly collaborative design journals and weekly online meeting records as minor assessment items to reinforce the collaboration, and to encourage the students to exercise the core skills.

Communication in 3D virtual worlds: In general, communication presents a challenge in virtual worlds. A number of factors constrain these interactions, for example:

- A lack of visual cues and auditory input might affect the quality of shared understanding. Even when visual cues are used (e.g. augmented with video conferences or web cameras) team members' abilities to communicate using non-verbal interactions (such as body language) can be inhibited (Hoyt, 2000).
- The technology does present some advantages when communicating over distance as they often allow more focused and concise information exchange between team members (Gabriel and Maher, 1999, Maher and Simoff, 2000), and assist team members keeping to their task (Cleland and Ireland, 2002).
- In addition Baird et al (2000) find that the virtual environment may not foster skills such as feedback. Furthermore, Williams and Cowdroy (2002) note that communication is easier if team members have previously worked together.
- Synchronicity is also an issue as virtual teams can operate in both synchronous and asynchronous virtual environments (Maher and Simoff, 2000).
- Research has shown that simply mimicking co-located settings such as teleconferences may result in fewer social interactions between team members as well as difficulties in sharing visual information (Gabriel and Maher, 1999).

Our students collaborated both synchronously and asynchronously. Synchronous collaboration usually occurs during allocated meetings in remote locations and studio. The students also reported that they used in-Worlds communication tools which based on text as well as other synchronized platforms such as Microsoft MSM, and asynchronous communication tools such as email.

Collaborative design process in 3D virtual worlds: Understanding the processes of collaborative design is crucial for the development of learning materials and tools in virtual environments. Collaborative design activity requires the participation of individuals for sharing information and organizing design task and resources (Chiu, 2002). Kvan et al. (1997) point out that as collaborators come together in design, the nature of their activity does not change, since collaboration still requires a designer to attend to design as an individual tasks, as well as collaborating. With the recent developments in virtual environments, there is a change in the way that design-related professionals collaborate and design. Researchers (Gül and Maher, 2006, Maher et al., 2006) point out that the design process and the realization process are different between the co-located sketching and the designing in 3D virtual worlds. Therefore it is necessary to consider those differences during course development. The results of the study indicate that:

- Designing in 3D virtual worlds encourage immediate and detailed design decisions: The designers had the situation of immediacy to construct the design representation in the 3D virtual world, rather than exploring alternative design solutions. They concretized their design solution without much iteration in the design process actions. They decided on a particular design idea and constructed it.
- Designing in 3D virtual worlds encourage individual designing on the model: The designers stayed in the distributed design situation in the 3D virtual world, where they worked on the modeling individually and came together for the negotiation and evaluation, staying in low-level design ideas.
- Spatial adjacency of the objects become the main activity: The designers created the 3D model through the "continue" action in longer spans, thus allowing them to focus on the spatial relationships of the 3D objects (see Gül, 2007 for more details).

Consistent with the findings from the above collaborative design studies, we observe that students maintained the same design concept which was developed in the early stages and spent most of their time on developing and refining the model and the implementation. Structured collaborative activities including task allocations, determining the roles and monitoring the process are also occurred during the project.

5. CONCLUDING REMARKS

3D virtual worlds have the potential to make a major contribution to design education as constructivist learning environments. This paper discusses how AW and SL as design and learning environments facilitate constructivist learning by investigating the affordances and constraints of modeling, communication and computational features of 3D virtual worlds. In addition, the paper presents core skills that are required for students to be developed in 3D virtual worlds. The paper also point out the differences of designing in 3D virtual worlds in relation to co-located design environments. To design and implement successful learning environments using 3D virtual worlds require careful integration and adaptation of these factors. We conclude the following issues based on our experience in teaching the "Designing Virtual Worlds" course.

Learning environment design: The environment needs to be carefully designed as most of the current virtual worlds are not specifically developed for education and are not readily to be used. Further 3D virtual worlds are constructivist allowing learning by "doing" and experimenting. Therefore academics should set the design problems and tasks to be complex enough to facilitate and encourage the challenges and explorations of new ideas and knowledge to make full use of the "virtuality". In addition, the design problem should require employing critical thinking and cognitive skills. The learning environment design should address teaching and learning supports as well as peer supports and to include them as "in-world" features forming an integral part of the learning environment. Finally, the learning environment design should reflect the latest development of 3D virtual world design and research as well as the focus of the course. This is very important, as the design of this environment is one of the few examples that will form the students' early understanding of virtual world design. The virtual world design should also be modified and adjusted accordingly and regularly to reflect the class size and student background.

Skill development: Designing in 3D virtual worlds requires technical knowledge and skills of different applications, media and interfaces/devices. It also requires successfully realizations of core skills during teamwork. Thus students should be given series of tutorial sessions that teach basic skills and knowledge of using these applications and tools as well as exercising various core skills for communicating and collaborating in 3D virtual worlds. It is also possible to consider forming student groups that contain experts from different disciplines who possess different skill sets for the collaborative projects. Another important point is that exchanging ideas, sharing design documents (sketches, images, visual ideas and etc.) and sharing and developing design concepts and knowledge are essential for engaging students in collaborative design.

Course development and moderation: Design content and technology content should be carefully balanced to match the students' backgrounds and capabilities as well as to suit the different teaching focus. Students should also expand their knowledge and skills to operate on variety of information and communication technologies integrated in the virtual learning environments. Monitoring the progress of students learning is essential in all design-related subjects. This requires ongoing evaluation of students design activities, which also provides the students and the teaching staff with feedback as the projects progress.

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