EVALUATING THE USE OF 3D VIRTUAL WORLDS IN COLLABORATIVE DESIGN LEARNING

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ABSTRACT: 3D virtual worlds for collaborative design learning have been widely recognized and practised, nevertheless there is a general lack of formal evaluation with empirical evidence for the performance of virtual worlds, and their roles in developing students’ teamwork skills. In bridging these gaps, this paper provides a critical discussion of the effectiveness of virtual worlds for collaborative design learning, supported by a comprehensive analysis on the results of an inclusive questionnaire completed by architectural students. The paper provides insight into the application of virtual worlds in both technical and procedural experiences, and discusses the benefits and shortcomings of virtual worlds on design education.

KEYWORDS: 3D Virtual words, collaborative design, virtual design studios and design education

RÉSUMÉ: Les mondes virtuels tridimensionnels pour l’apprentissage de conception collaborative ont été largement reconnus et utilisés. Néanmoins, il y a un manque général de l’évaluation formelle et des preuves empiriques de la performance de ceux-ci, ainsi que leur rôle dans le développement de la compétence de travail en équipe chez les étudiants. Afin de combler ces lacunes, cet article fournit une critique de l’efficacité des mondes virtuels pour l’apprentissage de conception collaborative, appuyée par une analyse complète sur les résultats d’un questionnaire rempli par des étudiants en architecture. L’article donne également un aperçu de l’application des mondes virtuels dans des expériences techniques et procédurales, et discute les avantages et les inconvénients des mondes virtuels dans l’enseignement du design.

MOTS-CLÉS: Mondes virtuels tridimensionnels, conception collaborative, atelier virtuel de design et enseignement du design

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1. INTRODUCTION AND BACKGROUND

The emergence of communication and collaborative technologies presents many previously unavailable opportunities for design collaboration. In design education, these technologies have formed new design platforms for collaborative learning as students can now collectively develop and document design without being physically located together. 3D virtual worlds are the latest development of such technologies, which focus on the application and support of an integrated virtual learning environment for collaborative design, supporting synchronous communication, collaborative modelling and constructivist learning.

The most notable example of adopting virtual worlds in design education is the concept and development of virtual design studios (Kubicki et al. 2004; Schnabel et al 2001). Since 1990s, virtual design studios have been set up by architecture and design institutes allowing remote collaboration on design projects. Commercial 3D virtual world platforms such as Second Life (www.secondlife.com) and Active Worlds (www.activeworlds.com) also establish virtual campuses specifically for learning. Over the years, design educators have explored different applications of 3D virtual worlds in design learning and reflected on their experiences. For example, it is argued that virtual design studios allow students to learn more about the design process, while the traditional design education has focused on the product (Kvan 2001); 3D virtual worlds can provide “experiential” and “situated” learning (Dickey 2005); The role of place in virtual learning environments can encourage “collaboration and constructivism” (Clark and Maher 2005); The use of 3D virtual worlds can support social awareness when students from different cultural backgrounds design and learn collaboratively (Wyeld et al. 2006). 3D virtual worlds as an emerging technology for design collaboration and learning have been indeed widely recognised and practised, nevertheless there is a general lack of formal evaluation with empirical evidence for (1) the performance of 3D virtual worlds in supporting collaborative design learning, and (2) the roles of 3D virtual worlds in developing students’ teamwork skills during collaboration. Aiming to address these two issues, this paper provides a critical discussion of the effectiveness of 3D virtual worlds for collaborative design learning, supported by a comprehensive analysis on the results of an inclusive questionnaire, conducted in 2008 at the end of a collaborative architectural studio. The paper draws on the results of the study and provides insight into the application of virtual worlds in both technical and procedural experiences. The paper also discusses the benefits and shortcomings of these collaborative learning platforms on design education.
2. THE COLLABORATIVE ARCHITECTURAL STUDIO

The collaborative architectural studio was conducted in August 2008. The studio was the result of an on-going international collaboration between the University of Newcastle, Australia and Rangsit University, Thailand. “NU Genesis”, a virtual island in Second Life was set up as the studio place as well as the site for designing and implementing the collaborative project.

Besides the use of Second Life as the main collaborative design and learning platform, students were introduced to a wide range of synchronous and asynchronous design and communication tools, and were encouraged to adopt and apply these technologies in supporting their collaboration as needed. Each student group was required to maintain a weekly log. The log serves as a tool for monitoring their collaboration, and for self-reflection.

2.1. Course aim and setup

The aim of this course was for students (1) to understand and develop the essential skills of collaborative design and modelling using 3D virtual worlds; and (2) to develop the understanding and hands-on experience of 3D virtual worlds as an extension of conventional architectural design. The course content has two major components: (1) understanding collaborative design in 3D virtual worlds; and (2) developing the essential skills for collaborative design in 3D virtual worlds. In order for students to develop the understanding of collaborative design in 3D virtual worlds, firstly, relevant theories such as the development of core skills for teamwork, as well as design and collaborative cases in 3D virtual worlds were introduced and discussed. Secondly, students were guided to inhabit and critically assess a wide variety of design examples in 3D virtual worlds, as well as various design and communication features supported in 3D virtual worlds. In order for the students to develop and practice the design and collaborative skills in 3D virtual worlds, a remote collaborative design project was used as the major assessment item.

The collaboration in 2008 attracted 36 Newcastle students from the second year undergraduate architecture program. They were divided into groups consisting of three to four individuals. Each group was then allocated with a remote collaborator from Rangsit University, who were enrolled in their third year undergraduate architecture program. Students from both universities remotely collaborated over the period of 5 weeks on a design project titled “Virtual Home”. The weekly studio included a one-hour lecture/instruction and a two-hour design/discussion. Students were also encouraged to collaborate after these scheduled studio hours.
2.2. The “Virtual Home” design project

With scheduled supervision in design development supplemented by tutorials for technical skill development, the collaborative design project titled “Virtual Home” provided opportunities for students to (1) experience and practice collaborative design in 3D virtual world, and (2) develop and apply design principles and technical skills for virtual world design. The design brief requires each group to design and implement a place in Second Life, which will demonstrate their concept of a “Virtual Home” and this will challenge the boundaries of a physical home (developed earlier by students in a traditional studio). The design outcomes and the collaborative experience of each group were documented in a slide presentation.

3. QUESTIONNAIRE RESULT AND DISCUSSION

To understand the effectiveness of 3D virtual worlds for collaborative design learning, this study collects and analyses evidences from students’ perception, and reflects on our own experiences in planning, conducting and assessing the collaborative architectural studio. We adopt a quantitative research approach to study students’ perception using an inclusive questionnaire. At the end of the collaborative architectural studio, students who completed the studio were asked to answer this questionnaire. The questionnaire consists of three parts of 34 questions in total.

- Technical features (answered on a five-point Likert scale): part one of the questionnaire aims to evaluate the performance of various technical features in 3D virtual worlds for supporting collaborative design and learning activities, in relation to general synchronous and asynchronous communication tools.
- Teamwork skill development (answered on a five-point Likert scale): part two of the questionnaire focuses on surveying students’ awareness and perception of teamwork skill development in 3D virtual worlds.
- Open questions: the questionnaire ends with a set of open questions in order to develop more in-depth understanding of students’ perception and expectation of 3D virtual worlds in supporting collaborative design learning. Students reported and discussed issues ranging from communication mode, design representation, design documentation, project management, to conflict resolution and other teamwork skill development in 3D virtual worlds.

The sample size of the study is quite ideal with 32 from a class of 36 students responding. 44% of the participated students are female. 70% of the students have two to three years design experience. 22% of them have only one year design experience. All students have at least one year experience in using gen-
eral CAD tools. 100% of the students have a personal computer and only 17% of them do not have internet connection at home, which implies that the students are quite well computer literate. However, a majority of 96% of the students experienced 3D virtual worlds such as Second Life for the first time. The students are therefore considered as both novice designers and novice virtual world users. We summarise the questionnaire results indicating students’ perception of 3D virtual worlds for collaborative design learning in the following sections.

3.1. Design support

Students have been largely divided regarding their satisfactory level on 3D virtual worlds in supporting decision-making and design solutions that came out of the collaboration. 39% of the students rated their experiences as neutral, and 39% of the students were “dissatisfied/very dissatisfied”. As shown in the following direct quotes from the students, their opinions are often conflicting, reflecting on both the strength and weakness of 3D virtual worlds from their collaborative experience, and in relation to features of general CAD applications that are familiar to them.

“... 3D collaborative modelling ... instantaneous and easy to relate ... I like that the group could see objects being made instantaneously ... could discuss ... dislike that it was hard to meet at the same time”.

“... is not compatible with other rendering software and has basic modelling technologies. But application of textures and lighting is excellent ... very easy and quick for modelling”.

“3D is easier to understand the concept of the design and gives an impression of how it looks/behaves ... Second Life was an entertaining, novel mode of communication, but was not often helpful, as it required every group member to be online”.

3.2. Communication

32% of the students considered 3D virtual worlds for communication were “effective/very effective”. 42% of the students considered the synchronous communication mode in 3D virtual worlds as neutral when comparing to asynchronous communication tools such as email. Once again, students’ perception has been largely divided; indicating significant differences in the affordance of new design communication technologies among students, even when they have similar background and experience.

- Students are divided about comparing synchronous communication in 3D virtual worlds with other asynchronous web-based communication technologies such as blogs and wikis. 35% of the students considered the synchronous chat channel in Second Life as “effective/very effective”, as a tool
to communicate design ideas. whilst 33% of the students rated “not effective/not very effective”. Selected comments from the students include: “... Synchronous (communication) was most effective when meeting however asynchronous (communication was most effective) when organising meetings and giving group information”. “… Text-based chat was the most appropriate. Audio can be a helpful tool but depends on the connection”.
• 45% of the students considered that other popular web-based communication tools such as MSN messenger a more effective synchronous communication tool than Second Life. 42% of the students rated as neutral.

3.3. Teamwork

Teamwork skill development remains as the most challenging aspect in applying 3D virtual worlds for design collaboration. Students indicate that it has been difficult to work together as a group due to the inability of having group members meeting face-to-face. 51% of the participants “agreed/strongly agreed” with this statement as they considered “… Face-to-face meeting was the most productive”, and 25% “disagreed/strongly disagreed”. Further:

• 51% of the students considered managing team activities difficult in remote design collaboration.
• 55% of the students failed to establish a plan or procedure collectively within their groups for working together.
• Nevertheless, 40% of the students do “agreed/strongly agreed” that teamwork tasks encouraged collaborative learning. 42% of the students were not sure as they rated neutral. 48% of the students also believed that they gained knowledge and skills from their group members during the collaborative project.

Commenting on the use of 3D virtual worlds for coordinating team activities in relation to other means, some students considered “… Email was good because we did not need to coordinate meeting times. Second Life, face-to-face (meeting) and phone call were good to get fast responses …” Some students indicated the reason that their group did not prefer email for design communication is because “… people did not regularly check their emails and therefore it slowed down (the) progress”, and the reason they preferred 3D virtual worlds was because they “… could communicate instantly whilst exploring options and activities”.

3.4. Summary

The above results of the questionnaire indicate polarisation among students over the user perception and tool preference during the design collaboration in 3D virtual worlds. The results together with our observation on and discussion with the students unveil some challenging aspects, especially the issues related to the affordance of new technologies and the management of team-
work, when applying 3D virtual worlds for collaborative design learning. They have also directly impacted on the overall satisfaction of students. The outcomes of the collaborative project as shown in the next session clearly indicate that the students are able to develop, collaborate and implement designs in 3D virtual worlds to a satisfactory level. However, the questionnaire results show that students have been frustrated with various issues emerging from the collaboration including: lack of design support in 3D virtual worlds; inability in teamwork management; delay in responses from collaborators; language barriers; cultural differences; lack of shared design understanding; and lack of common goal in collaboration. Students’ answers also highlight the following virtual world features that require future development:

- More comprehensive features for design development: the 3D mode of design representation allows clearer and more effective design communication among group members, compared to 2D sketches. The 3D representation provides an instant visual feedback of design creation and modification. There is a need for better support of collaborative 3D modelling including referencing and virtual “pointing” of design models, more complex 3D modelling and model sharing including: version control, compatibility with professional CAD applications and standards. Students also suggest possible add-ons to customise virtual worlds for design collaboration in specific design disciplines, and the capability to import and export more design and modelling resources for collaboration (for example, direct information flow with professional CAD applications), in order to enhance collaborative design and modelling.
- More support for teamwork: additional tools that support collaboration are necessary, at the moment, it is very difficult to keep track of design development in a group collaborative session. Effective monitoring of group design activities will increase the level of engagement for remote team and encourage participation.

4. OUTCOMES OF THE COLLABORATIVE ARCHITECTURAL STUDIO

Based on the above questionnaire result and discussion, 3D virtual worlds as a potential platform for collaborative design learning remain to be challenging to some design students. To extend the use of 3D virtual worlds in design education will require further considerations. However our early experience of applying 3D virtual worlds in the collaborative architectural studio has exhibited a wide range of potentials. Students demonstrate formidable abilities in adopting various communication and collaboration features supported in 3D virtual worlds for design development, and they also widely explore new design potentials in virtual worlds, as demonstrated in the outcomes of the collaborative design.
4.1. Exploring creative design

The potential of 3D virtual worlds as alternative means for exploring creative design is promising. For example, in order to plan and divide the “NU-Genesis” island for the collaborative “Virtual Home” project, an in-class design competition was conducted. The winning proposal excels in its novel concept of the “Three Worlds” layout for the zoning development of the “NU-Genesis” island. This winning design nicely addresses the conflict between the limitation of the virtual island’s buildable surfaces and the large number of enrolled students, to enable the sites to be arranged vertically. As a result, the island has been used to its full limit because the designs can arise from three different layers: under the “water”, on the “ground”, and in the “sky”. This also provides many unusual sites to enable the emergence of interesting design solutions. As demonstrated later in the collaborative project, many groups were very interested in selecting an unusual site, for example, an “underwater” site or a floating site in the “sky”, which they rarely could work with in a conventional architectural studio.

Selected designs of “Virtual Homes” are displayed in Figure 1, each of which represents a different approach to virtual world design. We briefly summarise each of the selected design as followed:

- “Sky Garden” (on a “sky” site): the design explores the idea of a virtual home as series of relaxing gardens. This design is most similar to real-world designs.
- “Archi-Bio” (on a “ground” site): the design is inspired by bio-mechanisms and transforms those dynamic and growing “homes” into their virtual home in Second Life.
- “Metamorphosis” (on a “underwater” site): the concept mainly revolves around Krishnamurti’s philosophy of “Living without Conflict” where materiality of the physical world conflicts with a person’s inner self. The design shows different levels of sub-consciousness through different layers of underwater rooms with familiar artefacts but aims to create ambient environments that depict different emotions.
- “Floating Cubes” (on a “sky” site): the group presents home as series of floating cubes that shift the occupants from one activity to another and from one mind set to another.
- “Zero Gravity” (on a “sky” site): virtual worlds have no physical constraints such as gravity but still support various activities. This design uses (non) gravity as the design trigger to challenge the constraint of gravity and to have different spaces hanging upside down within a sphere.
- “}{” (on a “underwater” site): The name of the group is a representation of a butterfly - a symbol of “freedom” - that you cannot verbally “say” it. The virtual home here is a place of communication inspired by poetry.
A combination of different degrees of realism in form and abstractness in concept assist us in understanding and evaluating different designs evolved from the collaborative architectural studio. Non-realistic and abstract designs often receive higher recognition in the studio as they often represent a novel way in approaching design and emerge to break out from the conventional designs with innovative and challenging solutions. They also often lead to more interesting outcomes and encourage students to explore different design possibilities other than repeating what they have already learnt in the conventional architecture studio (the students have developed a house project in an earlier traditional studio).

Two different design approaches have emerged from the collaborative studio. The first is the form-based approach where students start with the exploration of interesting forms, then adopt or sometimes even “make up” a concept afterwards. “Sky Garden” and “Floating Cubes” are among some of the groups that follow this approach. It is noted that these groups can often quickly reach certain design solution and move on to detailed design and documentation, as their design collaboration begins with form making and detailed modelling. The second is the concept-based approach, where students firstly explore, develop and agree on concepts that are more in-depth, and then realise the concepts through 3D models and other forms. “Metamorphosis” and “Zero Gravity” are among the groups that adopt this approach. They often progress slowly especially in the early stage of the collaboration compared to the groups that adopt the form-based approach. However, their design outcomes often become more sophisticated and interesting, if they can successfully communicate and realise the key concepts within the groups.
4.2. Supporting collaborative design development

Students have been able to explore and adopt a wide range of visual aids from 3D virtual worlds, as shown in Figure 2, in assisting their group communication.

**FIGURE 2. DIFFERENT VISUAL AIDS USED DURING DESIGN COLLABORATION.**

In Figure 2, the left-hand-side image shows a “group photo” captured directly from Second Life. The individual identity in 3D virtual worlds during collaboration appears to be an essential factor. Students not only spend considerable amount of time in customising their avatars in order to reinforce their virtual identities, functionally they often used avatars as the reference points when referring to design elements and 3D models during collaboration, for example, they often made statements such as “the floor above YOU” and so on. In some designs, avatars also become an important part of the virtual home. In most of the design presentations produced by the groups, avatars have been used to help in presenting the experience in inhabiting the virtual home. In addition, students import 2D scanned sketches, as shown in the middle of Figure 2, into 3D virtual worlds for synchronous communication. They also export screen shots, as shown on the right-hand-side of Figure 2, from 3D virtual worlds for asynchronous communication such as email attachments.

Some groups have demonstrated a very high level of competency in applying and adopting 3D virtual world features for different design phases. For example, in the “Archi-Bio” project, students successfully demonstrate how the group can strategically use different features in 3D virtual worlds to develop from the initial concept in the form of a scanned image that inspires their design (Figure 2 left-hand-side) to the abstract 3D volumes that assist their conceptual development (Figure 2 middle) and to their final detailed implementation of the virtual home (Figure 2 right-hand-side).
5. CONCLUSION

This paper presents an application of 3D virtual worlds in a collaborative architectural studio, conducted by the University of Newcastle, Australia and Rangsit University, Thailand. The use of 3D virtual worlds as a novel approach for collaborative design learning is evaluated based on students’ perceptions through a questionnaire. Our experiences show that the studio has offered students unique opportunities for design collaboration in remote locations; and for exploration of creative design. Besides the above findings regarding collaborative design learning in 3D virtual worlds, the paper concludes with the following remarks.

5.1. Design support in 3D virtual worlds

Based on the questionnaire results and our observations in the studio, we have identified the affordances and constraints of 3D virtual worlds in collaborative design learning. The approach for evaluating the design support in 3D virtual worlds is drawn from the affordance theory (Dickey 2007). Gül (2008) points out that different virtual environments provide different affordances impacting on designers’/learners’ behaviours. 

**Design and modelling**: in terms of affordance, the latest 3D virtual world development such as Second Life supports the parametric modelling method, which comprises a set of 3D models whose forms are determined inside the virtual design environment by selecting geometric types and manipulating their parameters. The models can also be freely adjusted at a later stage. Most 3D virtual worlds also support different viewpoints such as first-person view and third-person view during modelling. Therefore 3D virtual worlds well support the understanding of spatial arrangement in the design; and the development of students’ spatial abilities. 

In terms of constraints, although 3D virtual worlds enable students to start designing/modelling from the very early conceptual stage using basic 3D geometric forms, however, this can be challenging and inadequate for some students as they comment that they often have to sketch the design on papers in order to understand the overall design concept and layout, prior to modelling in 3D virtual worlds. Therefore, supports for different modes of design
development and representation such as 2D sketching and 3D modelling, and their autonomous interactions will be very desirable for the future development of 3D virtual worlds, in order to better support design development and to suit different design preferences.

Collaboration and awareness: in terms of affordance, most virtual worlds support synchronous collaboration. They often have a text-based chat channel for communication. In some virtual worlds such as Second Life, the ownership of 3D models can be flexibly arranged and shared to support collaborative modelling. Most virtual worlds afford the presence of designers/learners and their collaborators (the awareness of self and others) through the chat channel and the representation of the avatars; the use of place metaphor (the awareness of the design/learning environments); and the use of way finding aids (the awareness of navigation and orientation).

In terms of constraints, although 3D virtual worlds allows individual avatars to move freely around the collaborative design environment while still providing information about the shared design representation and the position of the collaborators (via the presence of the avatars), however the technique of manipulating the design objects in some virtual worlds does not well support the awareness in the collaborative design environment. For example in Active Worlds, designers are only able to see the results of other’s modelling actions but not the modelling process. Therefore monitoring collaboration and coordinating each other’s design/modelling activities can become very difficult. In the newer generation of virtual worlds such as Second Life, more awareness is provided through the so-called “consequential communication” and “feed-through” during the collaboration. In “consequential communication”, the characteristic movements of an action (for example, typing includes hand movements or walking includes legs and body movements) 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 Second Life, when a designer is creating a 3D model, the model is highlighted and the “link” between the designer’s avatar and the model is visible to other collaborators. These features support awareness in the collaborative design environment through “consequential communication”. In addition, when a designer is rotating or moving a 3D model, these manipulations are also visible to the collaborators. This is an example of “feed-through” behaviours that support awareness in the collaborative design environment. Without these supports for awareness, students will often have difficulty in understanding each other’s actions and are less likely to carry out a collaborative task successfully.
5.2. Collaboration in design learning

**Degree of collaboration:** Teamwork and group discussion should lead to developing a participatory environment that is essential to increase a shared understanding of design. Ideally, the groups should include students with different backgrounds and interests. Students should distribute the task according to the interests and skills and gain hand-on experience of working in a design team situation. As a group, students should have the same goal to successfully address the given design problem. Based on this shared goal, the key aspect of collaborative learning will more likely become the consensus through collaboration by group members.

**Management of collaboration:** Management of design collaboration is essential for the successful completion of the tasks. Students should be encouraged to use web-based management tools for collaboration management purposes, which may includes: task management (allocation and monitoring), meeting scheduling and minutes, design and communication document sharing, and so on. With the use of these tools the students will more likely to develop the understanding and gain hands-on experience of collaboration in a design situation. This also helps students with learning by experiencing and reflecting on their own progress and experience.

**Complexity of collaboration:** The nature and complexity of collaborative tasks to be used as the triggers for designing and learning in 3D virtual worlds should be carefully considered. The design tasks should be complex enough to grasp students’ attention and also to be challenging enough, which requires employing cognitive skills.

**Cross-culture collaboration:** It has been observed that the international design collaboration in 3D virtual worlds such as this collaborative architectural studio can raise students’ awareness in working with different cultures, design traditions and language barriers. Nevertheless, these factors also become challenges contributing to the complexity of the collaboration. One direction of our future study will explore the supports in 3D virtual worlds and curriculum design for better address these cross-culture issues of design collaboration in 3D virtual worlds.

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