

VIRTUAL & AUGMENTED STUDIO ENVIRONMENT (VASE)

Developing the Virtual Reality Eco-System for Design Studios

TIAN TIAN LO¹ and MARC AUREL SCHNABEL²

^{1,2}*Victoria University of Wellington*

¹*skyduo@gmail.com* ²*MarcAurel.Schnabel@vuw.ac.nz*

Abstract. Virtual Reality (VR) is being revived in major disciplines, including architecture. VR is no longer only employed for basic operations, such as construction of 3D models, dynamic renderings, closed-loop interaction, inside-out perspective and enhance sensory feedback. This paper explains how over the past twenty years technologies and software have evolved that a new eco-system for design processes have risen. This paper discusses how students made full use of both software and equipment in the whole design process; from ideas exploration to site analysis to form generation to design realization. Students have been exposed to a whole range of digital software tools in the beginning. As most of them were already familiar with modelling software, they have in particular been introduced to animation software, game engines and even 3D documentation software such as photogrammetry. Most importantly, they were led to IVE. The paper points out the benefits of adopting such methodology and the difficulties faced by the students at the various stages of the design process.

Keywords. Design Studio; Virtual Reality; Software and Equipment; Design Exchange.

1. Introduction

The understanding of VR is constantly changing with the advancement of technology. Maver and Alvarado (1999) defined VR as emergent computer technology for full 3D-simulation. At that time, the most advanced VR equipment was huge installation such as CAVEs and panoramic displays (Figure 1, left) to give users a sense of immersive-ness. The equipment usually was not very convenient that involved much hardware and required building spaces. Moreover, the interaction with the environment was very restrictive and not much of difference compared to working on a monitor. However, such experience was later used by Schnabel and Kvan (2001) only described as Virtual Environment (VE) and VR are defined as a visualisation technology to create total VE. For the first time, immersive VEs were successfully employed to create and communicate architectural design in a larger context (Schnabel et al., 2007). At present, VR is

no longer only employed for basic operations, such as construction of 3D models, dynamic renderings, closed-loop interaction, inside-out perspective and enhance sensory feedback (Sorguç et al., 2017). VR includes equipment that is compact with just a simple headset and hand-held pointers although there is an option that still requires a certain amount of building space to have manoeuvre capabilities within the environment (Figure 1, right).



Figure 1. (left) The Virtual Environment Lab at Strathclyde University (Maver et al., 2001) (right) The VR Lab at Victoria University of Wellington.

Latest VR equipment allows users to immerse themselves in a virtual social environment with multi-dimensional elements to enrich the design engagement. At the same time, the standard architectural software can easily be visualised in real-time interactive and social design experiences in a VR realm by innovative game-based platforms. Building information and other data are linked in real-time that it enriches and offers additionality within an immersed virtual environment (IVE). This paper reports on an investigation of how integrated use of various design software with VR equipment enhances the design exchange between design studio tutors and students. We also discuss in depth an eco-system among current VR software that enriches the workflow of design studios, leading to a much fulfilling experience. The findings of our research act as a basis for other educators of how to blend digital instruments and VR in a design studio setting.

2. VR in Architectural Design Education

The early nineties saw the emergence of one particular form of design studio, which investigated various possibilities that digital media and Virtual Environments (VE) can offer to the learning and the exploring of architectural design (Kvan, 2001). These Virtual Design Studios (VDS) established virtuality as acting while physically distant or as acting by employing digital tools (Maher et al., 2000). VE was established by choice of design (Achten, 2001), ways of communication (Schmitt, 1997) or digital tools (Kurmman, 1995). Later the VDS developed into real immersion within a VE, the medium for design interaction being the VE Design Studio (VeDS) (Schnabel, 2002). The advent of Web 2.0 technologies pushed the next logical step to develop the VDS with collaboration within a social learning environment. Ease of communication, leadership opportunity, democratic interaction, teamwork, and the sense of community are

some of the improved aspects that are offered by Social Networks (SN) (Owen et al., 2006). Mitchell (1995) also refers to the need for an ongoing evolution of the VDS towards a fully integrated studio where the borderlines between realms, professions, tools and mode of communications are dismantled. Subsequently, the advancement of VDS moves design education beyond conventional boundaries and curricula, engaging participants socially from diverse professional fields. This further leads to the Social Network VDS (SNVDS) which is subsequently the successor of the VDS enabling novel frontiers that enhance the deep learning within an interprofessional realm (Schnabel and Ham, 2012).

With the development of better and more immersive VR equipment, the experience and methodology of VR in the design studio is changing. Although students taking up architecture design courses use a broad range of software to push the boundary of their creativity, the introduction of VR-specialised software and hardware into the design studio changed the way students interact with their design. The students also faced a different type of challenge in the design process. Still, our research has found that by employing real-time social VR as a pedagogical approach there is an increase of the efficiency in design communication and design understanding for designers. Architecture students regularly build physical scaled-models to better experience the spatial qualities of their designs. Still, such models only provide a limited impression of their design and not enough to fully understand the extent of the practicality of their designs. Moreover, with the increase in design complexities, the time that is necessary to build the physical models, are no longer considered as sustainable option. This leads to the adaptation of IVE. Using IVE allows students to fully immerse themselves in their designed environment and experience first-hand the spatial quality that their designs provide.

3. The Eco-system of the Design Process

Maver and Petric (2003) suggested that within the context of design studios, the designers (D) being the centre of the design process among technologies will offer a rich set of opportunities (Figure 2, left). The technologies that involved then were only computer graphics (CG), rapid manufacture (RM) and laser scanning (LS). Then, Schnabel (2004) proposed a design cycle to expand the digital-integrated design process from mental idea to a physical result via virtual and real translation (Figure 2, right). Although the designer may still be the key person handling the design process, the focus is not in the technologies but in the various stages of the design process and how they can be connected as a loop for an enhanced result. The technologies are simply the tools to help realise and manipulate the design during the cycle. The design cycle dismantled the boundaries between the real and the VE to the extent that each crossed over to the other. VE can be an environment for design distinguishable from other tangible tools and yet facilitate tangible and real products.

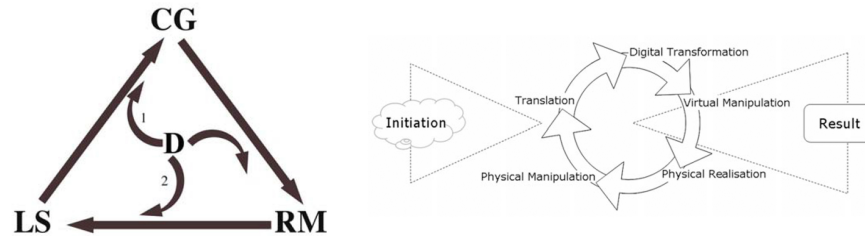


Figure 2. (left) Relationship of designer (D) to the technologies (Maver and Petric, 2003) (right) Design cycle (Schnabel et al., 2004).

However, there is still a gap between the imagination of a design and its representation, communication and realisation: architects use a variety of tools to bridge this gap. Digital tools are increasingly playing a role in bridging this gap yet the translation from physical to digital often poses a major barrier. It is common for students to use only the software that they are most familiar, a typical linear design process is using one software for a particular design purpose at different stages (Figure 3). This research, therefore, proposes a pedagogical model that let students use VR software and equipment as crucial part of their design engagements, allowing students to break free of this linear process and made use of a variety of resources in a very dynamic manner to reach their final design outcome.



Figure 3. Linear design process.

The idea of an eco-system is inspired by nature. In biology, an ecosystem is the connections between a community of plants and animals interacting with each other in a given area, even with the non-living environments such as weather and soil (Encyclopædia Britannica). Linking the constituents within the ecosystem are the flow of energy and the cycling of nutrients. Using the same connotation, in the context of design, the eco-system model that this research is proposing involved the connection between the software, hardware, users, and the intangible purpose/functionalities. There is only one key factor that is linking this eco-system; design creativity. With the increasing capabilities and complexities of design software, Maver's concept of designers being at the centre and Schnabel's idea of a design cycle can no longer keep up with the changing flow of creativity. The abundance of tech gadgets allows general users to be involved in the design process, making their role almost on par with the designers. Design creativity can be generated by any means and design methods like 'digital transformation' need not be followed by 'virtual manipulation' in the form of a cycle. Therefore,

the pedagogical model in the form of an eco-system is needed to expand the current understanding in order to comprehend the new technologies into the design studio. Figure 4 shows the intricate connections between the design software. Each software has its specialise function for a design purpose, although they are also capable of many other features, it is usually better to use software that specialises in a specific task. For example, *SketchUp* is mainly used for design exploration and form making, but it is also capable of generating sections and plans for documentation. However, the plans and sections are unable to be as detailed as those that are produced in *AutoCAD*. But again, by generating the plans and sections in *SketchUp* and import them into *AutoCAD* save a tremendous amount of time to redraw everything from the beginning. This interoperability is the key to the connectivity between the software.

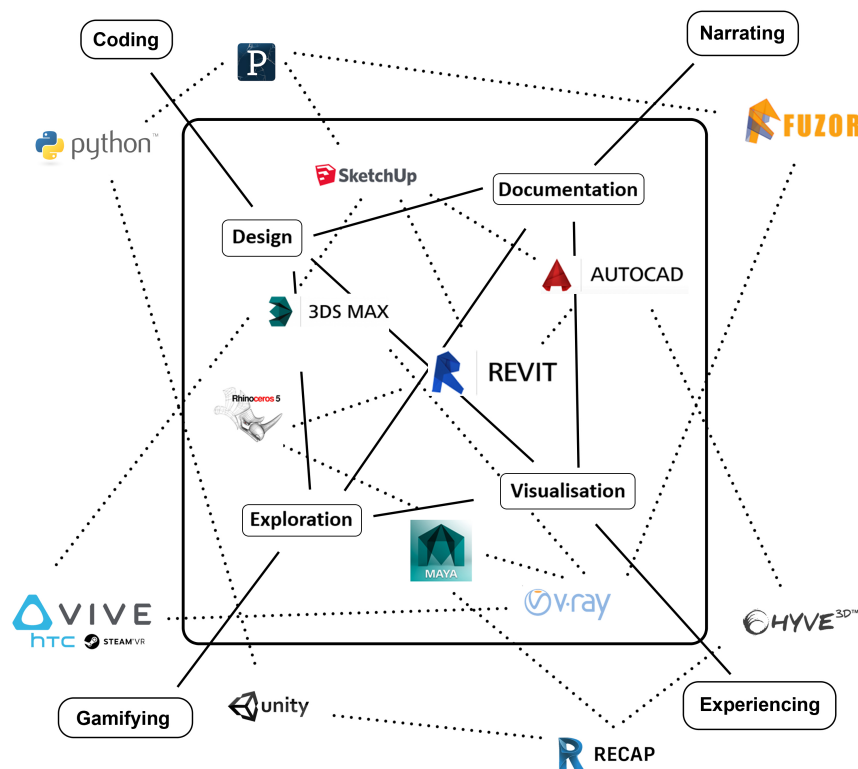


Figure 4. Dynamic Eco-system of the design process expanded from the conventional design process.

The connectivity between the software is the crucial factor that leads to the proposed eco-system. With the development of BIM software such as *Fuzor* that are capable of syncing model information with design modeling software and linking with VR hardware, design exploration is made possible within an immersive virtual environment. *Tile Brush* by Google took a leap forward

allowing designers to sketch in an immersive 3D virtual environment. Digital models can be imported into *Tilt Brush* from other modelling software to acts as the context for designers to start designing from (Figure 5, left). Innes (2017) then developed a system using *Unity* which allows designers to build geometry and manipulate them accordingly which is very similar to *SketchUp*, the only difference is that the operations are handles with the designers totally immersed in the VE (Figure 5, right). In general, it is not hard to observe that there already exist a certain form of eco-system. As described by Sorguç (2017), VR can be used even for the initial stage of design exploration. With the constant development of tools such as the one by Innes, the creative flow is breaking out of the conventional linear design process.

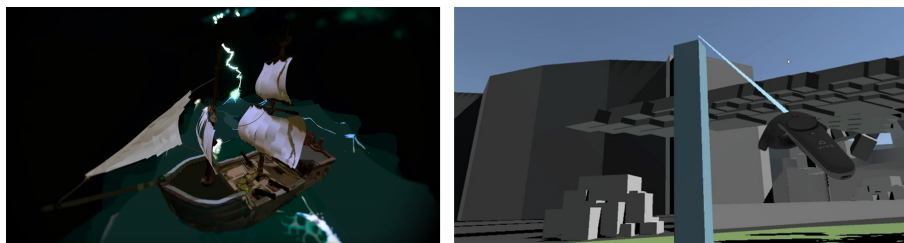


Figure 5. (left) Digital sketches made to an imported model of a ship in *Tilt Brush* (Dachis, 2016) (right) Creation of geometry in the VR application (Innes, 2017).

4. Design Studio

A design studio is conducted to demonstrate the dynamic eco-system of the design process. Based on the methodology of a conventional VDS and following Aristotle's concept of phronesis or practical wisdom (learning to judge when and where to put skill or knowledge into action) and drawing upon the arts to facilitate acquisition of knowledge (Dahlman, 2007), this design studio was set up to teach students the skills required for successful consultancy and interprofessional collaboration. This architectural design studio presented here is a core first-year design unit in the Masters' programme at Victoria University of Wellington (VUW). The studio operates in an on-campus mode with eleven students. The students were introduced to a design brief which is to design a railway station for the development of Wellington. The Wellington City Council (WCC) provided the aims and requirements that they are looking for in the design brief. The students were given the freedom to choose any site along the proposed railway tracks. They can use the software they were familiar with or explore new design tools but they need to fulfil one important component of the design studio; integrating the use of VR tools in the design process.

4.1. VUW VIRTUAL AND AUGMENTED STUDIO ENVIRONMENT (VASE)

A new Virtual and Augmented Studio Environment (VASE) has been established at VUW to push this frontier into the design studios. It has several large size monitors (Figure 6, left) that can be used for design presentation and virtual

communication. A few of the screens can be connected to provide the IVE that Maver has used in his lab in Figure 1 (left). It is also equipped with Virtual, Augmented and Mixed Reality (VAM) hardware such as several HTC Vive headsets, Microsoft HoloLens, and Hyve3D (Figure 6, right), an immersive design and visualization system.



Figure 6. (left) Large size monitors used for presentation and virtual communication (right) A user interacting with Hyve3D.

Hyve3D is an instrument that allows social interactions within VR. It differs from CAVEs, allowing collaborative and real-time sketching in 3D. The advantage of Hyve3D is that users do not need headsets and the setup allows shared interactions with 3D models inside an immersive environment without necessitating a complex graphical user interface (Schnabel et al., 2016). Most importantly, Hyve3D allows imports of models (OBJ format) and export the sketches done to other software (DXF format). This expands the connectivity of the software in the eco-system.

4.2. DYNAMIC DESIGN WORKFLOW BY STUDENTS

The students who took our design studio were overwhelmed by the expanded amount of software and hardware presented to them. They started the design process with their familiar software and hoped to achieve the aim of the design brief. However, the studio requires the students to generate a narrative experience of their design and allow people without much architectural technology knowledge (in this case, the WCC personals) to interact with their design. The students realised that the conventional tools could not fulfil the aim and started venturing into the VR tools and equipment.

One student, Jessie Rogers, pushed the concept of the eco-system to quite a great extent. She started off with a pedestrian simulation using *Quelea*, a plugin for *Rhino3D* to do agent-based simulation. Then, she went on to try scripting in *Grasshopper* to generate random drawings from images of graffiti arts. From those explorations, she decided to try manual sketching of lines using Hyve3D. In the end, she combined the qualities of the outputs to generate a design (Figure 7) that is very technically driven and architecturally refined.

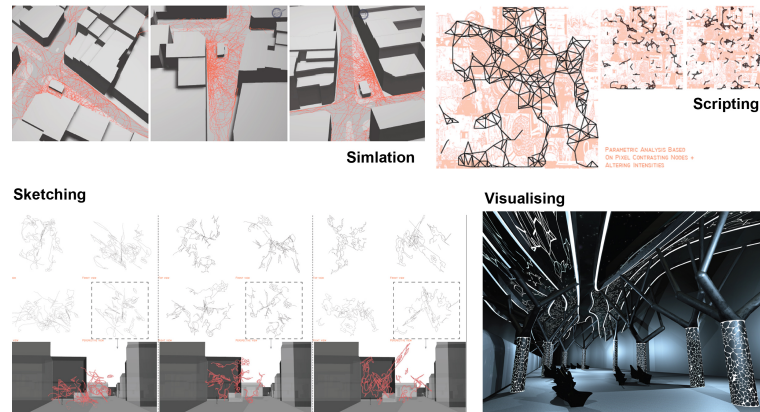


Figure 7. Design process and outcome by Jessie Rogers.

Another student, Duong Nguyen, became deeply engaged with the VR techniques and tried to integrate his material exploration into the design. He started off by trying the various VR tools and work with physical materials. He made use of photogrammetry to mimic the random organic form he created with the physical materials. He also went into scripting in *Grasshopper* with the intention to give his organic form a quantifiable mechanism. As he faced tough challenges in the design process, he eventually went into using *Google Tile Brush* to ‘draw’ his design ‘manually’ in a total IVE (Figure 8).

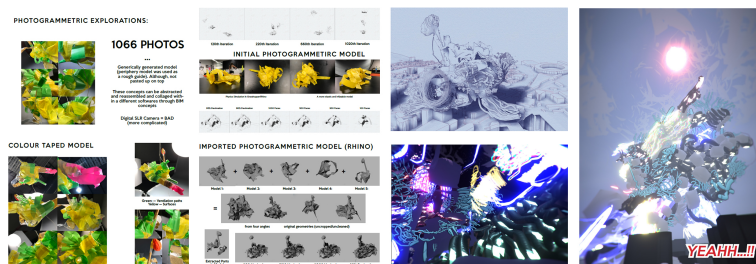


Figure 8. Design exploration and outcome by Duong Nguyen.

5. Discussion

By observing the students challenging themselves to integrate the VR tools and equipment into their conventional design method, we believe that a new eco-system for design processes have risen. The increase of VR tools suggests that Maver’s concept and Schnabel’s design cycle needs to be expanded for educators and students alike to embrace the growing software complexity to handle design creativity in design studios. Duong’s ambition towards duplicating his physical exploration digitally might have resulted in quite a chaotic outcome. However, the quality of his work is not in the design outcome, but the exploration process. His constant move from physical to virtual techniques is what constitutes the

eco-system. The challenge to close the gap between the real and the virtual still exists even with the help of VR tools. However, if more time is given to him, there is an opportunity that a certain flow within the complexity of the eco-system could help him achieve his goal. Jessie's effort in trying out the various tools and exploring all the possibilities of VR has not only enabled her to generate a distinct design outcome, but also expanded her means to present her ideas through digital narrative. She was able to make use of VR tool to engage the audience to experience and interact with her design immersively in the VE. The WCC personnel was very impressed with her output and published her design to allow the general public to also experience her design immersively. The VR tools give the capability that WCC needs; interaction with the public and gaining useful feedback.

5.1. TOWARDS SOCIAL NETWORK VE DESIGN STUDIO (SNVEDS)

Previously, Schnabel (2012) has established how SNVDS can enhance deep learning within an interprofessional realm. With VR and its capability for collaboration within a social learning environment, we believe that can easily lead to the establishment of a Social Network VE Design Studio (SNVeDS). The students engaged in the design studio make use of the VR technologies to bring their design to their fellow students to gain design feedbacks. Lo et al (2015) developed a collaborative VR design tool, ModRule, and engaged a group of designers in a design studio and the outcome was inspiring which brought about new synergies to the process. Although there is still much improvement in terms of software interoperabilities, the VASE has proven the concept that the eco-system raised in this research leads to a novel form of immersive and socially engaging design studio environment that allows for deep learning to happen.

6. Conclusion

This paper suggests that a VR eco-system exists and is necessary for design studios to bring out the full potential of VR technologies towards the development of architectural designs. It provides educators and students with a design approach that moves out of the conventional plans, section, elevation and 2D rendered output. This eco-system makes possible the movement of the design towards multi-dimensional experiences and narratives, allowing immersive social engagement of the community.

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