INTEGRATING DIGITAL MODELING AND FULL-SCALE CONSTRUCTION IN DESIGN STUDIO

BENG-KIANG TAN
National University of Singapore,
School of Design and Environment, Department of Architecture
akitanbk@nus.edu.sg

Abstract. This paper presents the observations of a design studio for undergraduates that adopted a hands-on, experiential approach where students combined both digital modeling and full-scale construction in their design process. The studio was designed as team-based to encourage peer learning and collaboration in design. The students used multiple media and engaged in tactile experience and through the process discovered by themselves the issues of translating digital design into full-scale construction and achieved a better understanding of construction, scale and materiality.

1. Introduction

Many papers have been written about the merits of either using 3D modeling or full-scale construction in design studio. In the past, we have conducted design studios using solely CAD 3D modeling for second-year students and they benefited from it. However, my observation is that some students do not have a good grasp of the scale of the project in "real life" size when modeling digitally. Thus, a design studio program was designed to leverage on the strength of both digital modeling and full-scale construction as design tools. This paper shares the experience of such a design studio. It starts with explaining the pedagogical objectives, followed by the process, and finally describes the lessons learned.

2. Objectives and Process

The studio, consisting of fifteen students, was one of the design studios for second-year undergraduate design course at the Department of Architecture, National University of Singapore conducted by a part-time instructor and myself.

2.1. PEDAGOGICAL OBJECTIVES

The pedagogical objectives were:

- to encourage peer learning and collaboration in design through team-based project
- for students to understand the process of translating a design on paper to built form through hands-on approach (an experiential learning)
- to focus on material and construction aspects of design
- to design with social and technological context

A design vehicle of a small two to three-person rapid deployment temporary shelter for earthquake victims was used to meet these objectives. Use of only one material i.e. cardboard was deliberately imposed on the students to focus their design problem. Students worked in teams of three persons.

The design criteria was that the shelter i) must be portable; ii) must be simple and quick to assemble; iii) components must be easy to handle; iv) must provide for comfort; v) must be built from paper honeycomb board (25mm thick) or 1200 x 2440 mm corrugated cardboard (7mm thick). A cardboard manufacturer sponsored the materials for the project.

2.2. PROCESS

The six-week studio consisted of two main phases. The first phase was information gathering and precedent studies. The second phase was applying findings from phase one to the design of a temporary shelter.

In phase one, collectively as a group, the students with the instructors identified the topics to research on. The topics were grouped under factors of consideration in an earthquake country and precedents of forms of temporary shelter. Under factors for consideration were environment and site, culture, psychology, support, material and morphology, and earthquake forces. The precedent studies investigated different forms of temporary shelter such as collapsible, assembly, umbrella, tensile, inflatable and expandable. As Singapore does not have earthquakes and these students have never experienced an earthquake, they had to understand the conditions through research and through talking to experts. A civil defence officer who took part in an earthquake rescue mission briefed the students and hosted a visit to view his department's facility and equipment. Friends overseas who had experienced earthquake served as resource persons for the students. The students also visited the cardboard factory to understand how the material is made and its properties. All findings were posted on a studio website shared with all students in this studio.

In phase two, the stages were Concept Design; Design Development; Fabrication; Assembly/Erection and Evaluation. The concept design was mainly done in paper media and design development in CAD 3D modeling. Each team built a digital model of their shelter and its components (Fig. 1) and demonstrated the possible configurations of placing multiple shelters on a site (Fig. 2). During the assembly stage, the teams erected their shelter in an indoor space for evaluation (Fig. 3 to 7). After which, to demonstrate the portability, they had to dismantle and re-assemble it outdoors. To evaluate for themselves whether their shelter is comfortable and can withstand climatic conditions, they stayed overnight in it.

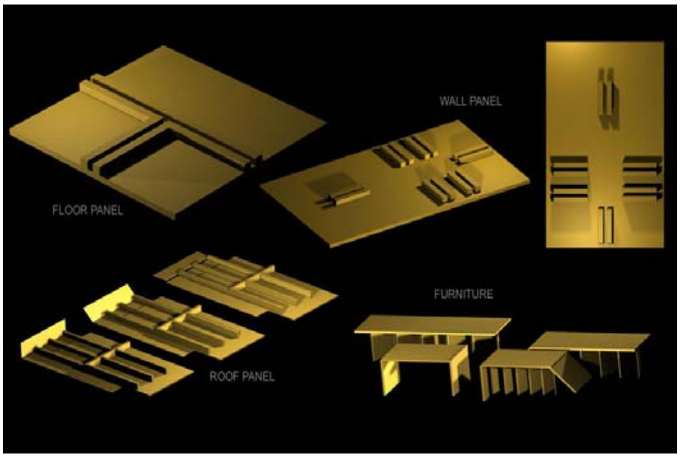

Figure 1. CAD 3D model of shelter components (Koh, Leng & Teo).

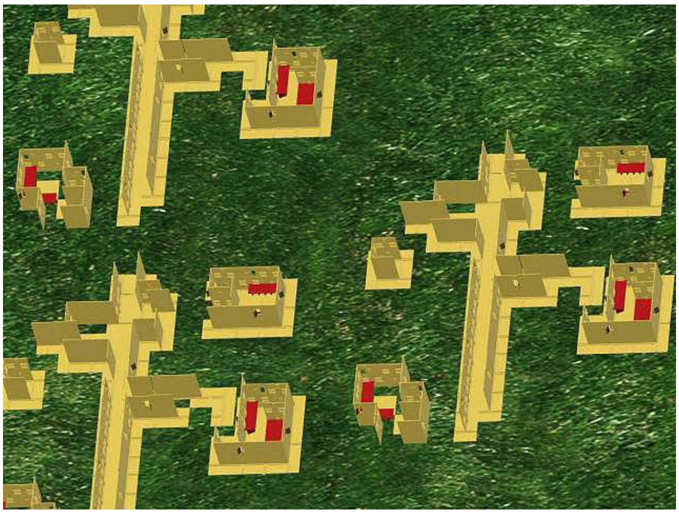

Figure 2. Site layout with multiple shelters (Koh, Leng & Teo).

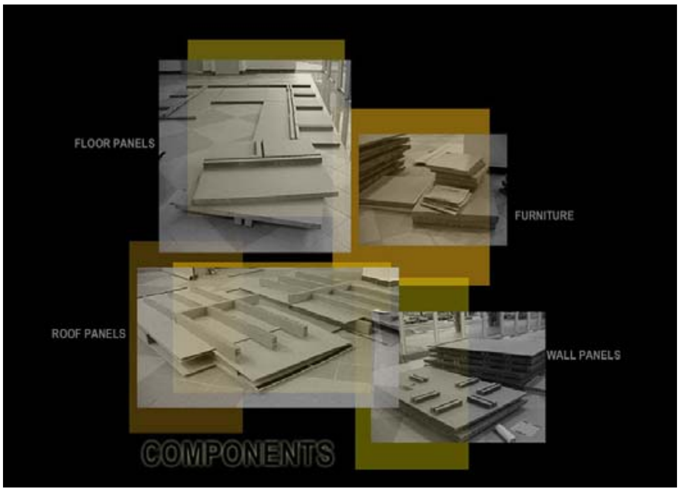

Figure 3. Full-scale components of the shelter (Koh, Leng & Teo).

Figure 4. Assembling a shelter (Koh, Leng & Teo).

Figure 5. Assembled full-scale shelter made of paper honeycomb board and corrugated cardboard (Koh, Leng & Teo).

Figure 6. Interior of shelter with bed and shelf. All made from paper honeycomb board (Koh, Leng & Teo).

Figure 7. Full-scale shelter made from corrugated cardboard and paper honeycomb board (Tan, Choy, Lim).

3. Lessons Learned

3.1. EXPERIENTIAL LEARNING AND ITERATIVE PROCESS

The studio program was very intensive. Even though the students had to work very hard to meet the tight schedule, they enjoyed the experience and felt that it was very enriching. Testing their paper proposal was a valuable experience they gained. Because the ultimate test of their design was whether the shelter could stand up and could be lived in, it was all the more rewarding when their design worked. Shelters by two teams fell apart soon after erection and that certainly made a lasting impression on the students of the feasibility of their design solution.

In the process of fabricating and assembling the full-scale model, inadequacies of their design solution surfaced and students had to modify their design, change their digital model and re-fabricate. This iterative process meant the learning was assimilated deeper and became a higher order of learning. The cardboard manufacturer, the civil defence officer and guest critics from Taiwan (who have experienced earthquakes) also attended the final crit and gave the students a chance to experience participation with "clients" akin to a real world situation.

3.2. CONSTRUCTION CONSIDERATIONS

Some team's designs looked good in the digital model and renderings with all components fitting perfectly but students found that during assembly of the full-scale physical shelter, the parts could not fit properly and they had to modify the component dimensions and re-cut the materials. They then realized that they should have designed for construction tolerances to deal with imprecision of fabrication. Without the instructor teaching them explicitly about construction tolerances, they understood the importance of it. This learning by reflection-in-action (Schon, 1985) sinks in deeper.

3.3. MATERIALITY

The drawback of CAD modeling is that one could model any building and it can look good even though the support system is not sound. One team's project looked good in the CAD model but collapsed shortly after erection. They reflected on the cause and were able to identify by themselves that the assembly method was not appropriate for the material.

3.4. SCALE

Novice designers usually have a problem grasping scale in the digital environment as CAD files have limitless boundary and one could zoom in and out easily losing the sense of the scale. Some students expressed surprise at the difference between their perceived scale of digital model and real-scale model with comments like “the shelter (referring to the full-size shelter) is smaller than I imagined from the drawing”. Another student summed up her experience as “I always do only tiny models joining parts together using superglue and leave it to my imagination how it is built and what it looks like. But with building 1:1 scale, I learnt a lot.” By going through the process of building full-size, they were able to appreciate scale better. Generally, they were excited about building and seeing their design in full-scale.

3.5. USING MULTIPLE MEDIA

Students were free to use any media (mode of representation) such as drawing, physical models or digital media (Fig. 8 to 10), for their concept design but they had to model their shelter design in 3D CAD. Each media was tapped for its strength. Most teams preferred doing their design concept with paper and sketches and their design development with 3D CAD. The act of sketching helped delineate ideas and its process of evolution. Doing physical mock-ups of parts of the shelter gave students the tactile experience of working with the material that a CAD model cannot provide. However, CAD modeling offered high accuracy of dimensions and forced the students to resolve their design to a greater detail. It also allowed the students to visualize the interior of the shelter before it was built and to explore different configuration of placing multiple shelters on a site (Fig. 11).

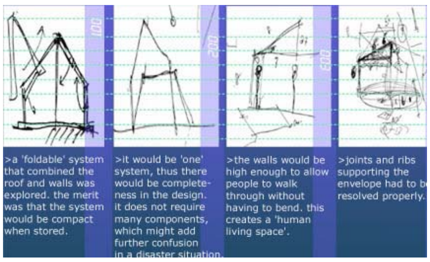

Figure 8. Process sketch (Goh W.K., Joshua Goh & Chow).

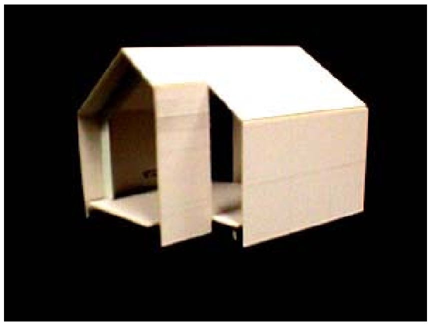

Figure 9. Small scale physical model (Goh W.K., Joshua Goh & Chow).

Figure 10. Digital model of shelter (Goh W.K., Joshua Goh & Chow).

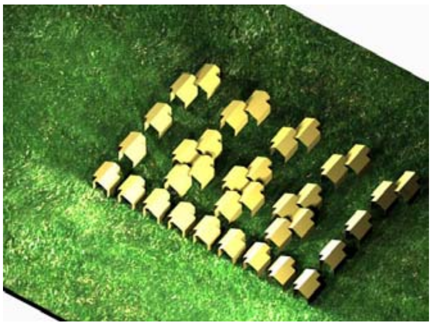

Figure 11. Digital model of site layout (Goh W.K., Joshua Goh & Chow).

Figure 12. Assembling full scale shelter (Goh W.K., Joshua Goh & Chow).

3.6. SOCIAL AND COMMUNICATION SKILLS

In real life, architects do not work alone. They collaborate and coordinate their work with other architects, engineers, contractors, developers etc. This studio exercise was successful in providing the opportunity for students to hone their social interaction and negotiation skills through working in teams and through their communication with parties outside the school environment. For instance, the manufacturer sponsored a limited quantity of cardboard materials so the students had to negotiate among themselves the allocation of limited cardboard materials. They also had to liaise with the manufacturer on logistics and timing of transporting the materials to school.

4. Conclusion

It was an enriching and fun experience for both instructors and the students even though the students had to work very hard to meet their deadline and the instructor had to do a lot more planning and logistics such as arranging visits, finding materials and space for students to build their full-size shelter. The students learnt to work in teams and felt proud of their team's achievements. The vehicle for design learning, a temporary shelter, was of appropriate scope and complexity for the project duration. However, a longer duration would have allowed the students to have more iterations of their design and understand better the integration of structural concepts into design. Unfortunately, it was not possible to have a longer duration within the framework and schedule of the entire year's design course.

While available financial resources, space, equipment, and safety concerns restricted the choice of construction materials, limiting it to one material meant that the design problem and process was more focus and students were compelled to think of innovative solutions. In this design project, the weakness of CAD as a medium that is "virtual" and "non-material" is complemented by the materiality of full-scale construction. Using multiple media and integrating digital model and full-size construction strengthens the learning process. Ultimately, both digital modeling and full-scale construction have a role in experiential design studio learning. With the advent of cheaper CAD/CAM equipment, this project process could be further explored using such equipment to cut down on fabrication time and allow for more iterations of design within the same time frame.

Acknowledgements

I wish to thank David Thomas, the part-time tutor, officers from the Singapore Civil Defence Force, Elite Paper, Prof. Chiu Mao-Lin and Prof. Jeng Taysheng from NCKU, Tainan, Taiwan and students who participated in this design studio.

References

Anthony, Kathryn H. : 1991, *Design juries on trial : the renaissance of the design studio*, New York : Van Nostrand Reinhold.

Mitchell, William and Malcom McCullough: 1995, *Digital Design Media*, New York.

Newton, Clare and Mark Burry: 2000, "Building Architecture - Using sticks, stones and computer visualization," *In* Tan BK, M. Tan and Wong YC (eds), *Proceedings of the 5th Conference on CAADRIA*, Singapore, pp. 511-519.

Schön, Donald A.: 1985, *The design studio : an exploration of its traditions and potentials*. London: RIBA Publications for RIBA Building Industry Trust.

________. : 1983, *The reflective practitioner : how professionals think in action*. London: Temple Smith.