Pencil, Pixels and Pulp: A Collaborative Design Studio with Digital Modeling and Full-scale Construction

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This paper presents the observations of a design studio for undergraduates that adopted a hands-on, collaborative and experiential approach to combining both digital modeling and full-scale construction in their design process. The studio was designed as team-based to encourage peer learning, knowledge sharing and collaboration in design. The students were engaged in multiple media and tactile experiences. Through this process, students explored the issues of translating digital design into full-scale construction and achieved a better understanding of construction, scale and materiality.

Keywords: collaborative design, digital design, design education, pedagogy, knowledge sharing

Introduction

In a knowledge-based economy, education needs to move away from teacher-centred learning to learner-centred learning. Knowledge sharing and design collaboration will occupy a more prominent role in design education and design practice. With this in mind, a design studio was structured for collaborative design incorporating knowledge sharing and leveraging on the strength of both digital modeling and full-scale construction. This paper shares the experience of such a design studio. It starts with explaining the objectives, followed by the process, and finally describes the lessons learned.

Objectives and Process

The studio consisted of eighteen second-year architectural undergraduates from the Department of Architecture, National University of Singapore. The design studio was conducted by a part-time instructor and myself.

Pedagogical objectives
The pedagogical objectives were:

- peer learning, knowledge sharing and collaboration in design through team-based project
- for students to understand translating a design on...
paper to built-form through hands-on approach (an experiential learning)
• to focus on the material and construction aspects of design
• to design with social and technological context in mind
• to extend their experience beyond the school boundary through participation by external parties

The design vehicle was a small rapid deployment temporary shelter for earthquake victims to house two to three persons. To focus on the design problem, students were allowed to use only one material i.e. cardboard. Students worked in teams of three persons.
The design criteria of the shelter include the following: 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.

Knowledge sharing
The six-week studio consisted of two main phases. Both phases were student-centred processes. The first phase was understanding the context of the problem with information gathering, precedent studies and then sharing the knowledge with the class. The second phase was applying knowledge from phase one to the design of a temporary shelter.
In phase one, the students collectively brainstormed and identified topics to research on with the instructors as the facilitators. As Singapore does not have earthquakes and these students have never experienced one, they had to understand the conditions through research and through talking to experts. A Singapore civil defence officer who took part in an overseas earthquake rescue mission shared his personal experience with the students. He also hosted a visit where the students viewed his department's facility and equipment. Friends overseas who had experienced earthquakes served as resource persons for the students.
The students also visited the cardboard factory to understand how the material is made and its properties. The research topics were grouped under factors of consideration in an earthquake country and precedents 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 ones. All findings were posted on a website and shared with the entire studio.

Collaborative Design
In phase two, the stages were concept design; design development; fabrication; assembly/erection and evaluation. Team members collaborated to come up with a design. The concept design was mainly done in paper media and design development in CAD 3D modeling.
Each team built a scaled model and digital model of their shelter and its components (Fig. 1). They also demonstrated the possible configurations of placing multiple shelters on a site. The students fabricated the design components full scale and erected their shelter in an indoor space for evaluation (Fig. 2 to 6). After which, to demonstrate portability, they had to dismantle and re-assemble it outdoors. They stayed in it overnight to experience for themselves whether their shelter is liveable and can withstand climatic conditions.

Lessons learned

Knowledge sharing
Each team researched on different topics and their findings were verbally presented in class and posted on a website. With this form of sharing, the students were able to achieve more comprehensive findings and analysis within a short period. The students
Figure 1
CAD 3D model of shelter components (Koh, Leng & Teo).

Figure 2
Full-scale components of the shelter (Koh, Leng & Teo).

Figure 3
Assembling a shelter (Koh, Leng & Teo).

Figure 4
Assembled full-scale shelter made of paper honeycomb board and corrugated cardboard (Koh, Leng & Teo).

Figure 5
Interior of shelter with bed and shelf. All made from paper honeycomb board (Koh, Leng & Teo).

Figure 6
Full-scale shelter made from corrugated cardboard and paper honeycomb board (Tan, Choy, Lim).
could also reference it anytime, at their own time during the design phase of the project.

**Construction knowledge**
Some designs that looked good in the digital model and renderings with all components fitting perfectly could not fit properly in full-scale. The students then realized that they should have designed for construction tolerances to deal with imprecision of fabrication. Without the instructor explicitly teaching them about construction tolerances, they understood the importance of it. This learning by reflection-in-action sinks in deeper.

**Experiential learning and iterative process**
These students grew up in a city where there is no DIY culture. They rarely repair or build anything by themselves at home. Testing their paper proposal with hands-on construction became a valuable experience for them. Shelters by two teams fell apart soon after erection and that certainly made a lasting impression on the students about the feasibility of their design solution. As the learning process required the students to live in the shelter that they had designed, this has allowed them to better understand building based on user’s needs.

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 attributed to a higher order of learning. The cardboard manufacturer, the civil defence officer and guest critics (via videoconference) from earthquake prone Taiwan also attended crit sessions and gave the students a chance to experience participation with ‘clients’ akin to a real world situation (Fig. 7 and 8).

**Using multiple media**
Students were free to use any mode of representation such as drawing, physical models or digital media (Fig. 9 to 11) for their concept design but they were required 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 the shelter gave students the tactile experience of working with material that a CAD model cannot provide. However, CAD modeling offered high dimensional accuracy and compelled 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 easily explore different configurations of multiple shelters on a site (Fig. 12).

**Materiality**
The drawback of CAD modeling is that one could model any design that looks good even though the
support system is not sound. One team’s project looked good in the CAD model but collapsed shortly after assembly. They reflected on the cause and were able to identify on their own that the design was not appropriate for the material.

**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, students were able to appreciate the concept of scale better and were excited about seeing their design materialized in full-size.

**Social, communication and collaboration skills**

In real life, architects do not work alone. They collaborate and coordinate their work with other architects, engineers, contractors, developers etc. This studio provided students the opportunity to hone their social interaction and negotiation skills through teamwork and 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 material delivery to school since school storage space is limited.

Conclusion

It was an enriching and fun experience for both instructors and the students even though the students spent sleepless nights trying to meet the tight schedule 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 collaborate in small teams as well as a collective studio group and felt proud of their team’s achievements. They benefited from sharing knowledge amongst themselves. 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 design iterations and a better understanding of the integration of structural concepts into design.

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 were 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 with 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, the process of this project could be further developed by cutting down on fabrication time and allowing for more design iterations within the same time frame.

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References


