Reforming Design Studios

Experiments in integrating bim, parametric design, digital fabrication, and interactive technology

Tienyu Wu[1], *Taysheng Jeng*[2]
[1] *National Cheng Kung University, Taiwan* [2] *National Cheng Kung University, Taiwan*
[1] *http://ty-design.blogspot.com/,* [2]*http://ialab.tw/ialab2010/main.php*
[1] *ty-design@hotmail.com,* [2]*tsjeng@mail.ncku.edu.tw*

Abstract. *Building Information Modelling (BIM) has been widely accepted as an integration tool that enables modelling of form, function, and behaviour of building systems and components. Using BIM, building design can be approached in a more logical way by integrating spatial, structural and mechanical systems as well as cost and energy performance in the early design stage. In this paper, we develop a design framework using BIM in varied design processes, including architectural programming, conceptual design, parametric design, digital fabrication, and interaction design. We conducted an experiment to reform design studios using BIM throughout the design process. A classroom of the future called iSTUDIO is constructed by applying BIM, parametric design, interactive technology, and digital fabrication.*
Keywords. *Building information model (BIM); Parametric Design; Digital Fabrication, Interaction Design*

INTRODUCTION

In the past decades, much effort has been done in developing a centralized digital representation of the building that is used to facilitate the exchange and interoperability of information in the building life cycle (Eastman, et.al. 2011). Few research works explored the use of BIM in conceptual design (Clayton, 2006). Some designers argued that adapting BIM activities in the design studio may pose a threat to design thinking (Denzer, 2008). Another educator argued that BIM is useful in understanding of building tectonics and can easily support the craft of building, systems integration, and documenting design work much faster (Eirik, 2010). A strong argument is that architects could not draw a building design without knowing building tectonics and components. To select evidence to support the argument, we conducted an experiment to reform design studios using BIM throughout the design process. We develop a classroom of the future called *iSTUDIO* by applying BIM, parametric design, interactive technology, and digital fabrication. This paper reports the result of the *iSTUDIO* project, and describes how to apply a BIM-centered design framework to designing a classroom of the future. The *iSTUDIO* is a two-years project for developing an adaptable, interactive, and smart classroom. The *iSTUDIO* classroom has been designed using several design software and involved with cross-disciplinary collaboration with designers and engineers.

This paper describes the future classroom design process of integrating professional teams by using BIM and parametric design. In the design process, BIM plays a crucial role to control the design parameters and information exchange between software, machines, and applications. For example, CAD/CAM tools can compile 3D models to machine codes for CNC laser cutters. BIM not only can help designers to efficiently communicate with teammates, but also prevent construction problems. The method used in the process of spatial design, the troubles of Implementation, and the integration of software applications require us to develop a BIM-centered framework.

Figure 1
A framework of BIM-centric integrated design process.

We develop a design framework using BIM to integrate varied design process. The BIM-centerted design framework includes five parts: architectural programming, conceptual design, parametric design, digital fabrication, and interaction design.

ARCHITECTURAL PROGRAMMING

With the rapid development of sensing and interactive technologies, opportunities for developing an interactive classroom by integrating authentic learning environments and the resources of the digital world have attracted much attention from designers and researchers in both the fields of architecture, human-computer interaction, and computing (OWP/P Cannon Design, 2010). To develop the classroom of the future, we initiated a research project called *iSTUDIO*. The *iSTUDIO* project started with the architectural programming phase in many of the higher education classes by observing, brainstorming, studying in the field, and interviewing teachers and students. Based on our observations, traditional classrooms have the following drawbacks: 1) lack of multi-way interaction and immediate sharing of knowledge among students, and 2) limitations and inflexibility of physical boundaries in classroom.

Two important criteria for future classrooms are *interaction* and *engagement*. To enhance interaction and engagement, we decided to design and construct an integrated digital-physical classroom of the future. The significant functions corresponding to the features are *tree-shape digital fabrication, transformable furniture, smart floor, real-time broadcasting,* and *an instant feedback virtual platform*.

To facilitate communication and documentation between project participants, we decided to use BIM as a single, parametric, 3D model to generate plans, sections, perspective, details, and schedules. Elements in BIM are managed and manipulated through a hierarchy of parameters. We used AutoCAD Revit Architecture as a BIM tool to construct 3D models. The 3D models support visualization of the design and allow us to improve communication and collaboration between participants. In the preliminary design phase, a 3D view of *iSTUDIO* was modeled, showing accurate physical conditions for the project, as shown in Figure 1.

CONCEPTUAL DESIGN

Inspired by Architect Louis I. Kahn's notion of first school that *"schools began with a man under a tree, and around him the listeners to the words of his mind",* we proposed an adaptive and interactive classroom with a natural atmosphere. The concept was implemented by making a tree shape inside the space. The tree shape was derived from an old banyan tree

Figure 2
The classroom before construction (Left); A 3D view of iSTUDIO showing accurate physical conditions for the project (Right).

of NCKU campus, which has long been considered as the symbol of NCKU. The tree shape was designed and turned out to be the section of the classroom, as shown in Figure 3.

Figure 3
The concept comes from the banyan tree of NCKU.

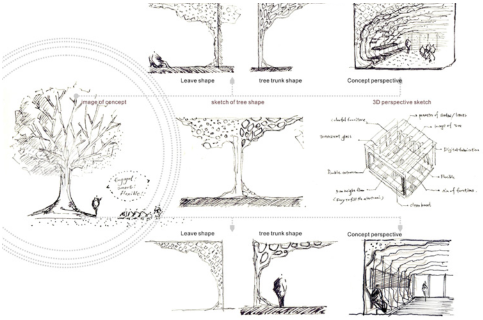


Figure 4
Sketches of the iSTUDIO classroom.

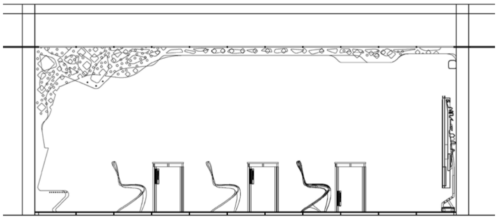


Figure 5
The final design drawing for digital fabrication.

The design project involved with a variety of professionals. Their background included architectural design, interior design, industrial design, interaction design, user interface design, computing, and mechanical engineering. Before implementation, our project team decided to use BIM as a tool to facilitate collaboration process and construction management of the classroom. The schedule included routine weekly meetings for five months.

PARAMETRIC DESIGN

The next step is to translate the sketch of tree shape into a real-world physical space. In order to implement the organic shape of trees, we used parameters to define a tree form and played its relations. The tree form turned out to be the section of the classroom.

The *iSTUDIO* prototype is implemented in a 40-square-metres classroom and can house up to 20 students. The classsroom prototype was equipped with transformable furniture that can be dynamically reconfigured into both a large whiteboard and desks for group discussions. A section view of the classroom is shown in Figure 5.

CNC machine helped us to mock up the prototype of the classroom. We mocked up physical models by using CNC machines and laser cutters. Then we used the prototypes to examine some limitations of joints and conducted assemble tests, as shown in Figure 6.

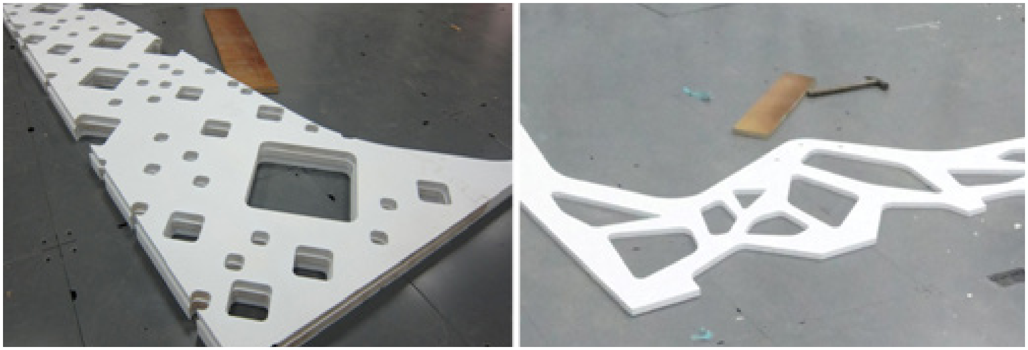


Figure 6
A tree-shape prototype produced by CNC machines.

BIM architectural software helped us to understand the process of design, controll the detail of 3D models, connect different parts of design, and adjust parameters. BIM provided an efficient method to translate 3D models into several digital fabrication files. For example, FBX, gbXML, SAT, DWF files for different design software.

DIGITAL FABRICATION

The next step is to construct a full-scale classroom with digital fabrication. Before construction, we use BIM software to help us to find design problems, to reduce design loops, and to improve the quality of models.

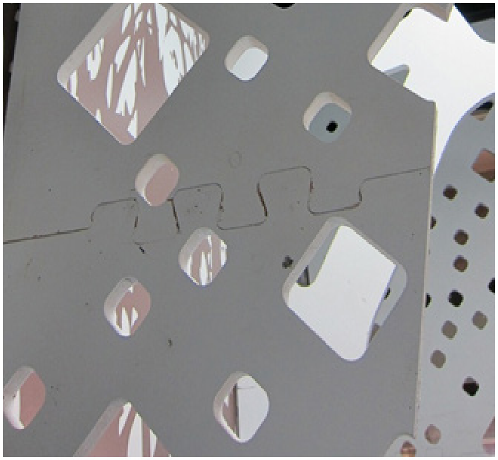


Figure 7
The joint of the tree-shape prototypes.

There was a problem that we did not find in experimental construction. For example, the joint of each wood panel required intensive coordination between designers, engineers, and contractors. The workers had abundant construction experiences in different fields: wood, painting, glass, mechanics, electronics, and CNC machines. It was challenging to negotiate with professional workers. The construction process required discussions and negotiated with workers, such as the specific color of paint, special joint of each wood panel, or the camera angels... etc.

INTERACTION DESIGN

In addition to spatial design, the classroom is equipped with ubiquitous computing technologies for interactive and collaborative learning. For example, light controls are integrated into the floor. Teachers can control the intensity of the light or turn it on and off by stepping on sensors on the floor. A web-based platform called "SynTag" was implemented for knowledge sharing. Lectures will be recorded and archived online for e-learning purposes. These recordings will also be annotated with the real-time comments and tags so students can see which parts of the lecture received the most responses (Hsu et.al, 2011).

A "Live" interactive tagging interface was implemented for collaborative learning (Chang et.al, 2011). The interface contains a real-time broadcasting system and a real-time interactive tagging system. The result of the construction is an innovative classroom

Figure 8
An overview of the iSTUDIO classroom.

Figure 9
Sensors are installed under the smart floor in iSTUDIO.

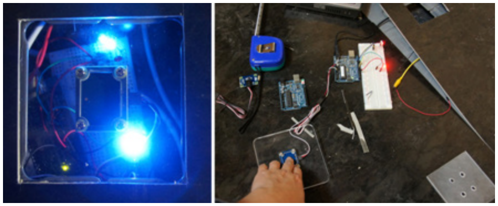
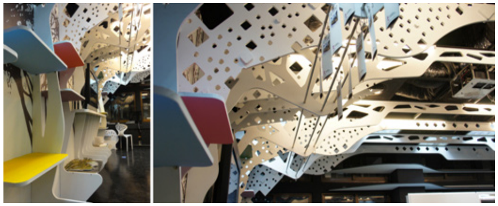


Figure 10
The "Tree" perspective of iSTUDIO after construction.



called *iSTUDIO*. The *iSTUDIO* classroom has been used for lectures, design critiques, and group discussion. Students enjoyed the *iSTUDIO*'s atmospheres. The new configuration of the *iSTUDIO* classroom creats more interactivity, flexibility, and engagement in learning.

CONCLUSION

Our experiment reveals that BIM can be used as an integrated tool for logical design thinking. Another finding is that BIM supports a collaborative design environment. It helps us to have efficient discussions by sharing information and data exchange. We can synchronously drawings, select materials and tectonics in detail by using BIM. Effective change management is another improvement. BIM not only becomes a platform for integration, but also a communication tool between team workers. Building an innovative classroom requires interdisciplinary researches using combined skills of specialists in design, interactive technology, networking, mechanical electronics. The *iSTUDIO* project is an experimental outcome of integrated cooperation. This experiment shows that BIM helps us to manage the design and construction processes. It also helps our interdisciplinary cooperation efficiently. Structuring building information has the potential to speed up collaboration process, control the building cost, and also improve logical design thinking.

ACKNOWLEDGEMENTS

This work was supported by the Taiwan National Science Council, grant No. NSC 100-2221-E-006 -224.

REFERENCES

Chang, S, Jeng T, and Yang Y, "Developing a Real-time Interactive Social Learning Platform Across Classroom Borders", *Proceedings of the 19th International Conference on Computers in Education (ICCE)*, T. Hirashima et al. (Eds.), November 28-December 2, Chiang Mai, Thailand.

Deutsch, R 2011, *BIM and Integrated Design: Strategies for Architectural Practice, Wiley*.

Denzer, AS and Hedges KE 2008, "From CAD to BIM: Educational Strategies for the Coming Paradigm Shift", *Proceedings of the AEI 2008 Conference*.

Eastman, CM, Teicholz, P, Sacks, R, and Liston, K 2008. *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Architects, Engineers, Contractors, and Fabricators*, Wiley, Hoboken, N.J. Hsu, Y, Jeng T, Shen Y, and Chen P 2011, "SynTag: A Web-based Platform for Labeling Real-Time Video", *Proceedings of the 2012 ACM Conference on Computer Supported Cooperative Work (CSCW)*, February 11-15, 2012, Seattle, Washington.

Mark, C 2006, "Replacing the 1950's Curriculum," ACADIA 2006, *Synthetic Landscapes/Digital Exchange*. p. 51.

OWP/P Cannon Design, VS Furniture, B. M. Design 2010, The Third Teacher: 79 Ways You Can Use Design to Transform Teaching & Learning, Abrams.

Weygant, RS 2011, *BIM Content Development: Standards, Strategies, and Best Practices, Wiley*. Sacks, R, Barak, R 2010, "Teaching Building Information Modeling as an Integral Part of Freshman Year Civil Engineering Education", *Journal of Professional Issues in Engineering Education and Practice*, 136:30.