

iSTUDIO: An Interactive Form-making Environment for Architectural Studio Pedagogy

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Abstract:

Unlike a conventional lecture class, the architecture design studio consists of sustained and multiple interactions between instructors, students, and their artifacts. One of the artifacts created and produced during these interactions is the physical study model. Often, the study model takes the form of a “straw man” around which design ideas and concepts are discussed, critiqued and modified. Because of the hands-on quality that a physical model affords, it appeals to the emotions through the tactility of materials and the mark of the human hand (Cheng, 1995). There is an ease in handling these models that allow for spontaneous visualization in the design process. However, physical models also have limitations. First, students spend a copious amount of time and labor in producing these models which can sometime adversely affect creative ideation and exploration of alternatives. Second, the model materials are relatively expensive and often unusable once complete. Sometimes the models are too ‘finished’ for the instructor to intervene in the student’s design process in a timely way, and even if they do, instructors might be inhibited in tampering with finished products that are painstakingly conducted by students.

Given these challenges with physical models, the advances of digital tools provide new opportunities to explore alternatives to physical models. However, digital models also have limitations in that they might appear overtly structured in their 2D flat-screen interfaces which can be real barriers to student-instructor interaction. Considering these relative merits and limitations of physical and digital models, our goal was to create the iStudio, a stereoscopic 3 dimensional digital form-making environment for the beginning architecture studio. The iStudio was not meant to replace the physical models but to act as a complementary avenue for visualization. Our goal was to allow for spontaneity in interaction, rapid replication, immersion and reduction of model cost/labor. Most importantly, the objective of iStudio was to develop a shared frame of reference so design ideas could co-evolve between students and instructors. The specific pedagogical objective of the iStudio was to facilitate: demonstration (students can instructors can “follow-along”), annotation (students and instructors can “model-over”), evaluation (students and instructors could get shared feedback), and peer interaction (students could collaborate with other students).

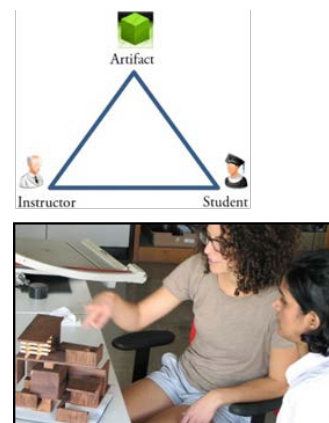
Key words

Architecture design studio, 3D model, virtual reality, design pedagogy

1. Model Making and Ways of Seeing

Architectural education relies primarily on studio-based learning where creative ideas are generated, critiqued and debated through a “learning-by-doing” culture. Within this context, architectural artifacts such as physical study models often play a primary role as the shared frame of reference to externalize the design process. Physical models are beneficial precisely because they are tactile and inhabit real space (Cheng, 1995). They are ambiguous and open for change and there is an ease in handling them that allow for spontaneous visualization. However, students tend to spend countless hours creating models with expensive materials that could easily wear-off. More often, majority of the student effort is spent on production instead of creative ideation.

Figure 1. Interaction in a typical studio class



One of the most significant features of architecture studio education is helping students 'see' the world through a shared frame of reference through which they can communicate ideas without ambiguity. Schon (1991) describes the intimate process of design as a reflective conversation between the studio instructor and design student and the emergence of design knowledge as "knowing-in-action." He suggests that designers are in transaction with the design situation and a designer's knowing-in-action involves sensory, bodily knowing that demonstrates the "seeing-moving-seeing" sequence of design thinking. The designer sees what is "there" in some representation of a site, draws in relation to it, and sees what is drawn, thereby informing further designing. This unique type of seeing allows designers to recognize, detect, discover, and appreciate. It follows that studio instructor does not try to solve student's design problem directly, as much as he or she reshapes it—or rather re-states the problem from its starting point.

Cheng (1995) observes that manual models appeal to the emotions through the tactility of materials and the mark of human hand. She says that physical models, communicate better than their flat screen simulations because sculptural objects inhabit the real space of the viewer, while frames isolate imaginary spaces. Physical models confront the viewer with their presence; interacting with the viewer by providing different appearances from different angles and reflecting lighting and images from the enclosing room. Cheng further observes that modeling with materials which are subject to some of the same physical forces provides an intuitive connection to our sensory experience of the environment. The imagination is charmed by little quirks and asymmetries that belie the human touch. Model building has an interactive appeal of the tactile, miniature and the unfinished. Models appeal to the emotions through the tactility of materials, miniaturization of scale and the mark of human hand.

More recently, design 'seeing' has been altered through the emergence of digital media in design. Designers and researchers have acknowledged a fundamental difficulty in design styles between computer aids and human cognition (D'souza, 2008). Many design schools are hence skeptical in bringing computers to bear in the beginning studio because of this disruption. D'souza has pointed out the limitations of digital tools in which designs have to be panned and zoomed to better grapple the wholeness of the design problem. D'souza points out that the digital tools force designers to think sequentially (starting from parts to whole) while manual models are holographic (where wholes and parts are reciprocally determined)(D'souza, 2007). In this experiment, digital tools aided slow and incremental growth, focused on linear ways of problem solving, and impeded spatial memory and hand-brain coordination. Manual model on the other hand aided rapid re-configuration, reciprocal form of problem-solving, ease in spatial memory and hand-brain coordination.

Although, it is not possible to generalize to the whole genre of digital technology, given the rapid advancements in recent years, table 1 provides a snap shot of the relative merits and limitations of physical and

digital models.

Table 1. Merits and demerits of using physical models vs. digital ones

	Merits	Limitations
Physical Models	- Ease in handling - Tactile & intuitive - Inhabit real space	- Time & Labor intensive - Painstakingly done - Not re-usable
Digital Models	- Does not easily wear-out - Rapid replication - Re-usable	- 2D Screen Less intuitive - Overtly structured

It should also be acknowledged that today's students are growing up in an entirely different learning environment than their design instructors. D'souza (2011), has suggested that design learning is significantly at odds with technologies that are impacting the new generation and the need to develop new learning environments.

It is also not pertinent to rule out that designers do not use models in a homogeneous way. Well-known designer such as Frank Gehry explains that when he and his team start a project, they play in plain and neutral blocks of wood for a long time until they get the organization and the scale right for the buildings on site (Rappolt and Violette, 2005). As soon as he understands the scale of the building and the relationship to the site and the client, he starts drawing. Those drawings give a sense of direction to the study models for his associates. He also sees a changing role for his study models which he uses model as a crutch. Gehry contends that he works more like a sculptor, molding, pushing, changing, and sketching back to the plan. Similarly other designers such as Zaha Hadid use computers only at a later stage of their conceptual process (Schumacher, 2004). Hadid observes that while she still does physical models and sketches, computers are just another way to do design.

Other designers see greater opportunities in the use of digital technologies. According to Schumacher (2004), the virtual three-dimensionality afforded by 3D modeling software offers a new way of working that combines the intuitive possibilities of physical model-making with the precision and immateriality of drawing. Further, 3D modeling introduces whole new series of "primitives" and manipulative operations which are highly suggestive with respect to new architectural morphologies and conceptual build-up of an architectural composition. Similarly, architect Peter Eisenman (Eisenman, 2012) observes that the uses of simulation technologies have directed a powerful challenge to architecture because it defines reality in terms of media and simulation; it values appearance over existence, what can be seen over what

is. Not the seeing as we formerly knew it, but rather a seeing that can no longer interpret. He observes that it is precisely this traditional concept of sight that the electronic paradigm questions.

2. Digital Affordance and Design

While the merits and demerits of manual and digital model continues to be debated, D'souza Balakrishnan, and Dicker (2012) have suggested a modest reframing of digital tools that moves away from its current usage as 'tools for design' to 'tools of design.' This reframing considers digital tools not as an aid to carry out a design task, rather, as 'design tools that happen to be digital.' The traditional role of digital tools such as efficiency, precision and form making, while valuable, should be balanced with intellectual core of architectural design discourse. Hence, they suggest to focus on digital affordances for design. Bricken (1990) recognizes the versatility of virtual and augmented tools for experiential learning and suggests that such digital technology enables the current generation of students to practice skills in ways that cannot be achieved in the physical world. Digital technology, for Bricken, provides a developmentally flexible supply and virtual learning materials that do not break or wear out.

In this context, some key digital technology affordances such as tangible interaction and embodiment might be most relevant to design. Tangible Interaction encompasses user interfaces and interaction approaches that emphasize tangibility and materiality of the interface, physical embodiment of data, whole-body interaction and the embedding of the interface in real spaces. Hornecker and Buur (2006) argue that tangible interaction focuses on the design of the interaction instead of the visible interface. This puts the qualities of the interaction into the foreground of attention, and requires designers to think about what people actually do with the system (Djajadiningrat et al 2000; Jensen et al 2005).

Embodiment is a concept that is extensively discussed in relation to virtual reality (VR). Dourish (2001) state that embodiment is "the property of our engagement with the world that allows us to make it meaningful" and that people and their actions are embodied elements of the everyday world." Wilson (2002) and Klemmer et al. (2006) suggests that embodied cognition is deeply dependent on the body's interactions with the world and that this physical interaction with the environment affects one's understanding of the real world. Others such as Kirsh (2013) are more forceful in stating that these tools change the way people think and perceive, and when tools are manipulated they are absorbed into the body schema, which changes the way people perceive the environment. Tangible interaction and embodiment hence consists of a variety of learning and educational benefits (Billinghurst, 2002; Chen, 2006; Kaufmann, 2003; Pasaréti et al., 2011; Shelton, 2002). The iStudio goal was hence to use digital technology affordances such as tangible interaction and embodiment as an alternative way of model-making.

3. The Context of iStudio

Our goal was to implement the iStudio in one component of a traditional studio of a mid-western school of design. The goal of this existing studio is to facilitate students to develop sensibilities to design principles of architecture such as visual composition, scale, balance etc. This exercise was conducted through a series of abstract exercises done by composing objects from a kit-of-parts consisting of 18 different shaped and sized wooden cubes, planes and sticks. While conducting these exercises students often use temporary rubber cement to glue the wooden objects so they can test it out

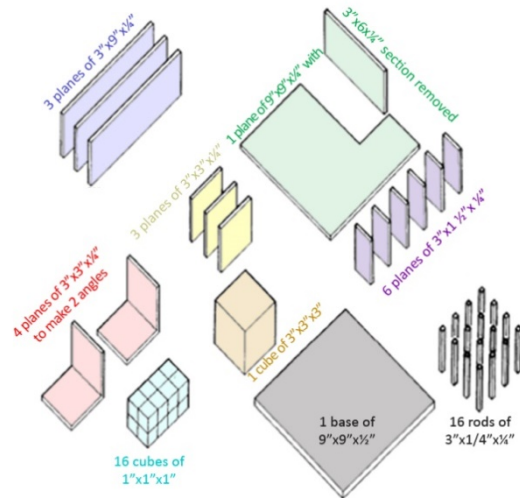
Table 2. Design principles practiced in each project

	Design Principles	
PROJECT 1: VOLUMETRIC EXPLORATION	Hierarchy	
	Balance/Unity	
	Solid/Void	
	Rhythm/Repetition	
PROJECT 2: TRANSFORMATION	Geometric Progression	
	Rotation	
	Sliding/Extending	
	Folding/ Wrap Around	
	Layering	

and modify if necessary. The kit-of-parts exercise is derived and modified from the book 'Creation in Space' by Jonathan Friedman, one which was inspired by the 'Nine-square Problem', developed at the University of Texas in the 50's and expounded at the Cooper Union in New York. Friedman (1995) describes these exercises as the formation, or arrangement, of elements in simple and

powerful combinations and then their rearrangement, that can express the progress and development of an idea by the composer or architect. In the first exercise, named as 'volumetric exploration' students use the kit-of-parts to create 3x3x3 inch cube composition on a 9-inch base. This exercise is designed to demonstrate their prowess in design principles such as 'hierarchy,' 'balance/unity,' 'solid/void' and 'rhythm/repetition.' In the next exercise, named as 'transformation' students transform the 3x3x3 inch cube composition into a 9x9x9 inch cube composition using additional objects from the kit-of-parts. This exercise is designed to demonstrate design principles of 'geometric progression,' 'rotation,' 'sliding/extending,' 'folding/wrap-around' and 'layering.'

Figure 2. Kit-of-parts (Friedman)



Cubes

16 cubes of 1"x1"x1"
1 cube of 3"x3"x3"

Planes

4 planes of 3"x3"x1/4"
3 planes of 3"x3"x1/4"
6 planes of 3"x1 1/2"x 1/4"
1 plane of 3"x6"x1/4"
3 planes of 3"x9"x1/4"
1 plane of 9"x9"x1/4" with 3"x6"x1/4" section removed

Rods and base

16 rods of 3"x1/4"x1/4"
1 base of 9"x9"x1/2"

Figure 3. Project Transformation from 3x3x3 cube to 9x9x9 cube

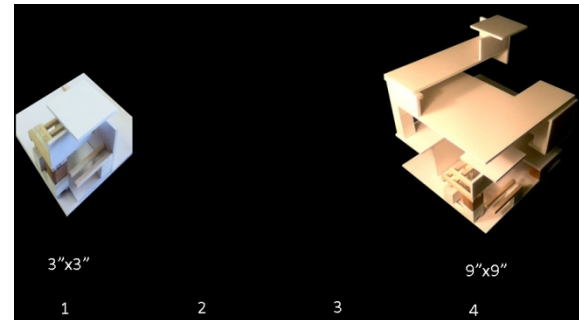


Figure 4. Study models and analytical drawings

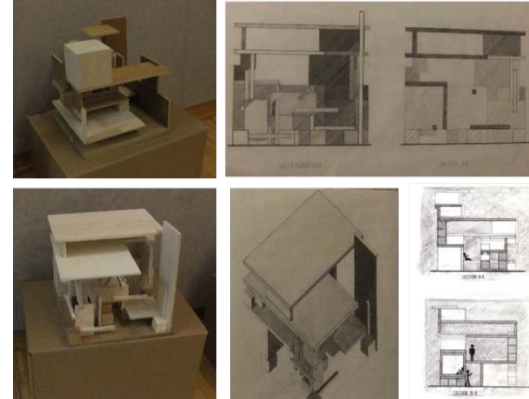
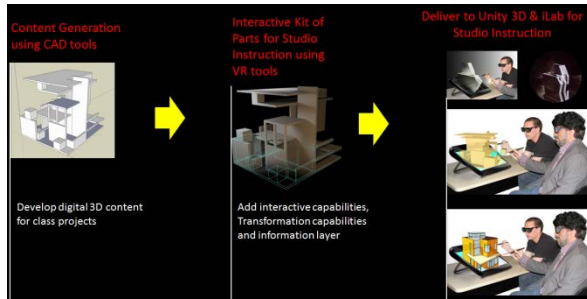


Figure 5. Final Exhibit



Figure 6. IStudio Workflow



4. Development of the iStudio

Before the implementation of the iStudio, the interaction between the student, instructor and the physical models were documented in the traditional studio first. The results of these studies provided more insights into the studio effectiveness. We found that students spent less time in ideation and were more focused on production. Because design principles, in general, are hard to quantify, we expected students to undertake the exercises repeatedly in order to refine their solutions. But we found that because of the cumbersome nature of attaching the parts they did not explore too many alternatives. Often times, the spontaneity of their thought process was slowed down waiting for the rubber cement to attach in a timely way. Moreover, while the instructors preferred the kit-of-parts to be made of wood it was relatively expensive. Hence, students relied on cheaper alternatives such as form core, cardboards and museum boards which was difficult to work with. Consequently, their work would reflect poor craftsmanship skills, which was detrimental to the aesthetics of their compositions. However, because of the physical and tangible nature of the kit-of-parts students were able to manipulate their compositions in a tactile way. They also were able to use the photography studio in order to study features of planes, light and shade more rigorously.

These findings provided us insights into the development of iStudio. However, rather than replicating the physical models in digital form, we focused on the digital affordances to develop the iStudio. Hence, we outlined the following pedagogical goals for the iStudio:

- *Demonstration:* Students should be able to see the instructor's gestures and their implications on digital models, so students can 'follow along' absorbing the choices and why they are being made. Instructors could also refer to past best practices and historic precedents as a way to open up students' understanding of important concepts.
- *Annotation:* Instructors should gain access to their students' models in a non-invasive, non-disruptive way and be able to "model over" in order to bring the student's attention to specific problems of perspective or proportion.

- *Evaluation:* Students and instructors should be able to get shared feedback on emerging ideas and timely remediation.
- *Peer interaction and collaboration:* Student-to-student interaction should occur where two or more students can collaborate and critique their ideas.

The iStudio was developed in two parts. The first component developed a digital studio kit-of-parts. We completed the basic modeling of elements in the kit using Sketchup software and used VR authoring tool Unity and Unreal to add interactive transformation (move, rotate, scale). The second component was to implement a shared representational platform to facilitate the exchange of ideas. We identified zSpace as a medium that can facilitate these interactions. The zSpace is a 3D display platform where the objects can be viewed, manipulated, analyzed, and shared in an immersive environment. It consists of a stereoscopic display, digital stylus for interaction, and polarized 3D glasses which are tracked to adjust the viewpoint.

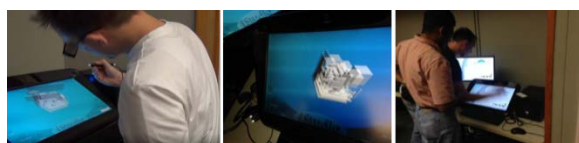
The basic primitive shapes were first created in Sketchup. This helped us to visualize the digital objects. Later the model was recreated in a 3D VR authoring software called Unity. While several game engines are available in the industry to develop VR, we used Unity because it allows VR developers to develop interactive VR applications in a seamless and simple way. To make the design exercise interactive, it was essential to be able to pick up objects and place them in the correct location. In order to do this we had to disable the features of gravity and throwing objects since they were not necessary for the purposes of the project.

In Unity, objects can be connected to each other through a PartConnector that manages connections to other parts. Connection between objects are made when the user puts one Part in contact with another, then let's go of the part while adding a FixedJoint. The result is that all parts act as one object. Transparent grid acts similar to the part connectors. When Part is released inside it, the grid creates a fixed joint and attaches it to the part. When the part is grabbed again then the fixed joints are removed.

Handling collisions in Unity can be difficult. This means changing how the object is attached to the hand and how it interacts when coming in contact with another object. Instead of being attached to the hand and moving where the hand goes, we had the object follow the hand the way a piece of metal would follow a magnet. This approach was challenging and caused jitteriness and rotation issues that could not be resolved. This resulted the removing of realistic collisions and allowing objects to pass through each other. Now that the basic functionality and foundation was set, extra features were added. The features were added to a Menu that spawns above the left hand. By default, all the parts are color-coded depending on the parts shape and dimensions. The new feature allows the user to change the material of all the parts and provide a homogenous appearance of a material such as wood.

To allow for more accurate placement of the Parts, the rotation caused by the hand's orientation was disabled. Meaning the part's rotation no longer relied on the hands rotation; instead it relies on the input on the controller's directional pad. The default rotation is 90 degrees but can be changed to 30 and 600 degrees through the menu. After this part of the work was done in the Unity software, we migrated to another VR authoring software called Unreal. Although Unity has an exceptional marketplace with several free assets, Unreal Engine 4 provides much better lighting for a more natural and vibrant look. Unreal Engine 4 also has a superior 3D user interface creation which allows for more freedom in developing an improved user interface. The engine also provides an editor mode where the developer can build the game from the perspective of VR. This and the graphical programming language that the engine also provides, allows for faster developing and testing. With the project moved to Unreal Engine 4, redoing the project took only a small fraction of time, and adding new features were made easier. The snapping of the objects location was implemented, so the object takes to position of the hand and rounds it to the nearest whole number value.

Figure 7. 3D stereoscopic Kit-of-parts



In the iStudio environment while we had to compromise on the tactility of the physical model, the 3D stereoscopic system helped us to visualize better than the 2D flat screen computers. The digital affordances of our environment helped us to implement certain features that could not be done in the physical model. They are as follows.

- Color coding: to facilitate analysis of different components of the models.
- Transparent grid (9 x 9): to facilitate the understanding of spatial and dimensional concepts.
- Snap to grid: to help students at beginning stages, in order to have easier control over the 3D component movement.
- Shade and shadow: to provide a real-time investigation of the models.
- Wireframe view: for better observation of the model
- Replication feature: to enable students to create a copy or multiple copies of their existing model.
- Whiteboard feature: for annotation and collaboration

5. Next Steps

We have adopted a design-based research strategy for this project that uses progressive refinement by testing, analyzing, and refining the design from very early stages

of development (Collins et al, 2004). While we have not conducted any summative evaluations for the iStudio environment yet, our formative assessment reveals lag between our input device and the interactions on screen. Hence, we are testing the project with various input devices such as data gloves and Vive controllers.

Figure 8. iStudio VR Environment



We are also experimenting with interfaces at various scales such as the zSpace, head-mounted and large-screen CAVE environments. Immersing student learners in multiple modalities of learning will reveal more understanding of its effects. The next steps will be to explore gesture based modeling with more advanced haptics so students can intuitively grasp the objects with physical force. Plans are on hand to also develop a digital tutoring system for self-learning.

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