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Prototyping Practice

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Prototyping Practice

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The best things happen when you have to deal with reality.
- Robert Venturi[1]

Architectural design does not end as the tools of fabrication are put into action. On the contrary, making is a discipline that can instigate rather than merely solve ideas – in other words, a design process.
- Bob Sheil[2]

Introduction

A prototype is defined as an early model, built to test a concept or process or to simulate a final product. In many fields, there is great uncertainty as to whether a new design will perform the way it is intended. For vehicles, products, and machines, the prototype is often the first full-size working version, and is produced in small batches to develop future iterations.

Designers use prototypes to explore alternatives, assess user experience, approve aesthetic decisions, and confirm performance prior to starting production. However, a variety of industries from software user interface designs to emerging building technologies, have extended and diversified this definition. Prototypes now include items and experiences in a broad array of mediums, and are no longer limited to physical constructions, digital models, spaces, and interactions.

In architectural practice, the seeming accuracy of virtual digital models makes them an increasingly desirable alternative to full-scale physical mockups. However, for beginning designers, the need to prototype at full scale is crucial. Understanding architectural space is intricately tied to scalar knowledge; the translation of design concepts from the virtual to the physical world is a decisive experiential step. Additionally, the practice of prototyping simulates the decision-making found in the real-world architectural design development process.

Context

This paper examines the employment of both low-resolution and high-resolution prototypes in a variety of fields to explore the applicability of these methods in a beginning design context. It proposes an approach that uses prototyping as an analog to the architectural design development process and examines this approach through student projects and reflections from a digital design and fabrication laboratory course. Taught in the spring semester 2013 at the University of Massachusetts Amherst, the assigned projects employ digital fabrication tools to provide an immediate feedback loop for beginning design investigations. While small projects cannot simulate the construction of large buildings, the logistical concerns precipitated by even simple digital fabrication processes can foster engagement with technical issues of material and assembly.

Low-Resolution Protoypes

Low-resolution prototypes have historically been used iteratively to design, construct, and test physical objects, assemblies, and spaces, increasing the fidelity of the model prior to production. As the design process has been exported to the business and service sector, the practice has become increasingly wide-spread in non-physical design endeavors.

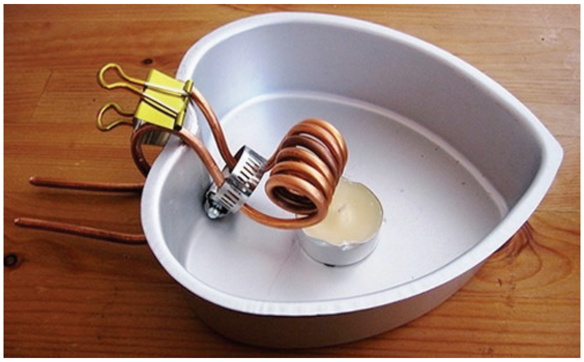

Fig. 1. Steam Engine Boat Toy Prototype on Open IDEO (Photo: Avi Solomon)

Tom Kelley, general manager of the design firm IDEO, values prototyping for its inherent bias toward action. In his 2005 book, the *Ten Faces of Innovation,* Kelley writes that "Experimenting in our world typically means prototyping, and prototyping is central to the IDEO tool set, as essential as a hammer is for a carpenter."[3] As the IDEO business model has expanded from products to experiences, services, and organizational structures, Kelley recognizes "Virtually every step along the ideation path can be prototyped - not just at the development stage, but also marketing, distribution, and even sales."[4]

Scott Berkun, former lead program manager at Microsoft, observes that for software and user interface design, low-resolution prototyping has economic benefits – it saves time and resources. In software and UI design, Berkun notes, "The value of the prototype is that it is a facade, like a Hollywood set, where only the front of the building is constructed."[5] He asserts that since prototypes are relatively inexpensive to produce, "For a minimal investment, you can find usability and design problems and adjust your UI before you invest heavily in the final design and technologies."[6]

The culture of producing many quick prototypes rather than a singular precious response is intended to reduce the fear of failure. In IDEO terminology, this rapid experimentation without material limitations is called Extreme Prototyping. Kelley explains, "We've also learned not to be precious about prototyping....We cycle through prototypes, and our first prototypes can be pretty darned crude."[7] (Fig. 1) Proponents of human-centered design assert that low fidelity prototyping can quickly focus attention on the design features that are most vital to the end user.[8] The prototype thus becomes a valuable tool for communicating with clients who may not share the same vocabulary as the designer. (Fig. 2)

Fig. 2. Prototype for a mobile app (Photo: Courtesy of Custom Future SA)

Berkun also cites the importance of prototyping in getting a team to coalesce around a vision for the project.[9] Similarly, Kelley posits that presenting multiple prototypes elevates the possibility of a productive dialogue about design and fends off fruitless reactions to individual design decisions by providing evidence for pros and cons of the design idea.[10]

High-Resolution Prototypes

In contrast to quick and crude low-resolution prototyping, designers have deployed high-resolution prototyping in architecture, engineering, and industry for a variety of purposes: to test new experimental building and material practices, to extend the limits of known construction methods, to test new assemblies, and to insure quality control in construction.

In the introduction to "Prototyping Architecture," the curator Michael Stacey identifies several prototypes that pushed the boundaries of conventional practice.[11] For example, in Frank Lloyd Wright's Johnson Wax Administration Building, the dendriform columns did not initially conform to the Wisconsin building code in the 1930's. Intended to carry loads varying from two to twenty tons, Wright built a full-scale prototype that withstood a load of sixty tons and enabled the Building Commission to issue a permit when their current formulas could not be applied.[12]

Fig. 3 Site Construction Mockup UMass Amherst

In architecture projects, site construction mockups are a critical prototype to establish clear standards for quality. On a functional level, these prototypes enable the team to determine contractor sequencing, test three-dimensional material transitions, and establish handoffs between the trades. (Fig. 3)

When site built, a construction mockup frames expectations and agreements for aesthetic and tectonic details. For example, in an architectural concrete project, a mockup can give the Design Team and the General Contractor confidence that the concrete subcontractor understands the design intent and has the necessary skill to carry out the contract. It also permits the subcontractor's laborers to become familiar with the specific formwork requirements and joint detailing in advance of the work.

Fig. 4. Apple eMate 300 Industrial Design Model Prototype (Photo: Jim Abeles)

In many product engineering and design workflows, a functional prototype will simulate the look, feel, materials, and usability of the intended design. (Fig. 4) Often made of less expensive materials or process, this final working model is a last check prior to more extensive manufacturing production runs.

Prototyping: an essential beginning design practice

The artificially "neat" division of high-resolution and low-resolution prototypes presented here is, actually, a continuum that maps need and function to material and timeline. The model of prototype as a means of testing prior to full-scale manufacturing still has validity in some modes of practice, but as more processes provide one-off manufacturing opportunities, there is a convergence of prototype and final model. Moreover, prototyping is also now an established design practice for goods as well as services, workflow, processes, and even organizational change. Thus, as architects embrace these design opportunities in an expanded field of practice[13], they can also expand the methods of prototyping in their design toolbox.

In some ways, the role of prototyping – making and testing – in the context of beginning design education is obvious. Design educators likely all agree that making is an essential aspect of learning by doing, as evidenced by the theme of this and previous beginning design conferences. Prototyping is inherently an experiential practice, which is the foundation of design education.

Prototyping: an agenda for beginning digital design

However, in the case of a beginning digital design sequence, these agendas may be more nuanced. First, the architecture and building industry is continually changing and will continue to do so during students' professional careers. This dynamism includes the use of digital design and manufacturing equipment for everything from model making to building fabrication. Thus, a curriculum founded on "making" now also includes teaching students to be comfortable and familiar with these tools early in the design process.

Second, and more critical within a digital sequence, is the experience of creating output from digital to physical as a hedge against the scale-less quality of the digital environment. Beginning designers can gain confidence in their own design decision-making by prototyping at a 1:1 scale. For these designers, the digital world is initially scale-less. Understanding architecture and designing for a real inhabited world are intricately tied to scalar knowledge. Extracting design ideas from the digital world to experience them in real life is a crucial step in all beginning design education, including digital design.

Third is an engagement with technical issues that provides an alternate track to the beginning studio's focus on conceptual design. Some schools bridge this divide with design-build courses, but this is not always feasible in the first year of education. This problem solving is particularly important in the study of an increasingly complex field where students are learning to design buildings but may not personally construct one in the course of their design education.

Lamp

This project provided an introduction to the laser cutter and its associated software. The brief charged students with the task of producing a three-dimensional object that exploited the properties of the tool and the materials, while exploring illumination with a limited palette. Allowable materials included opaque chipboard, mat board, basswood, and thin plywood; translucent and transparent materials were not permitted.

Fig. 5. Lamp during testing (Photo: Ryan Luczkowiak)

Student projects foregrounded sectioning and folding as the predominant strategies for transforming 2d material into 3d objects. Significantly, students struggled with the technical parameters of the light bulb. Choosing the appropriate bulb, managing the fittings, and modulating the light provided challenges that became catalysts for important design decisions.

Students universally recognized that within the digital environment, the possibilities were limitless. However, as the class assembled their first iterations, they encountered the limits presented by the demands of the geometries of specific bulbs and fittings, as well as the contingencies of mounting, hanging, or supporting the fixtures. (Fig. 5) Plugging in the bulbs for the first time in the darkened lab, the students also immediately discovered potential refinements. For students, the imperative to mesh performance - structural, material, light quality - with their previously purely sculptural criteria provided challenging terrain.

One student designed a radially organized pendant fixture intended to mimic the undulations of a mushroom. The student discovered that moving from the digital model into physical space revealed unanticipated structural considerations. (Fig. 6) He found the undulation had an unexpected effect on the lamp, producing an unevenly distributed weight around the central circle which required select "gills" to scale up in order to accommodate this dramatic movement.[15]

Fig. 6. Lamp Iteration (Photo: Nayef Mudawar)

Another student sought to capture the soft glowing qualities and translate the geometries of an existing historic light fixture. (Fig. 7) Through several iterations, he tested different materials, varied the number, size and profiles of the fins, and adjusted the base to provide more even distribution of light and the inner glow he sought. Describing this testing, he wrote, "Concerns that I faced were: Does the material work with the light (bulb) in terms of changes in color and light distribution? Does the material heat up when the light bulb has been on for a while? Is the material durable enough (longevity)?"[16]

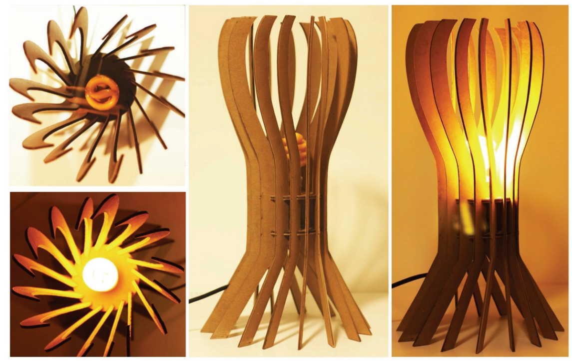

Fig. 7. Lamp Final Iteration (Photo: Tom Forker)

A third student focused on the intense infrastructure found in the basement site for his studio project. His lamp design celebrated the space's ever-present plumbing lines by integrating lighting with them. He enjoyed the challenges and constraints that accompany the fabrication's technical parameters writing, "The amount of work required to transform my initial design into a finished product was significant, but it was proportional to the increased satisfaction I felt in turning on my lamp for the first time, and being able to interact with a truly realized project."[17]

Screen

In the second project, students used parametric design tools to explore an element from an architectural studio project at the scale of the component. This exercise prompted them to consider pattern and porosity, which then informed their building scaled projects. Rather than moving in a linear design process from conceptual design in ever-increasing specificity to detail design, this project jumped scales to prototype a highly detailed element which, in turn, advanced their nascent studio work.

Students first plotted on paper, producing iterations of the entire screen at ¼" scale, and

12" x 12" sections at full scale. They then produced laser cut prototypes, which they evaluated at both scales.

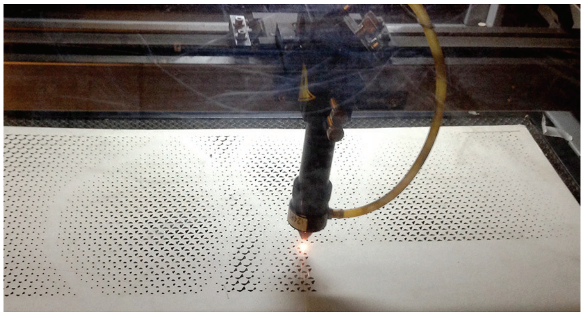

Fig. 8. Interior Partition Screen (Photo: Marcel Alvarez)

One student worked on an interior screen partition for a Habitat for Humanity dwelling with a modest square footage. This student found that working both at full and reduced scales enabled him to experience and then adjust the design to achieve the desired level of connection between the dining and living areas. (Figs. 8, 9)

For another student working on an urban apartment building facade, prototyping his screen facilitated testing patterning and appropriate porosity that would achieve interior daylighting while blocking undesirable views. (Fig. 10)

The laser cutter, as a tool, has a particularly entrancing quality. The level of precision that it affords scale models is powerfully seductive. For these students, after reviewing their intricate scaled screens, the shock of the full-scale prototypes was palpable. The ensuing iterations enabled resolution at both experiential and architectural scales.

Conclusion

Digital fabrication projects are pursued in design curriculum for myriad reasons. In this digital skills laboratory, the practice of prototyping specifically strengthens design skills through experiential knowledge acquisition.

How well did these projects provide an introduction to a basic digital fabrication workflow? Working on both two-dimensional and three-dimensional prototypes pushed students to engage the tool's interfaces and explore its potential. As the projects progressed, students fully integrated this workflow into their iterative design process.

How well did prototyping at a 1:1 scale strengthen design decision-making? The lamp project, as a full-scale object, fostered a significant breakthrough from the digital model to the physical artifact. The screen project then furthered students' abilities to relate an architecturally scaled element to their own bodily experience.

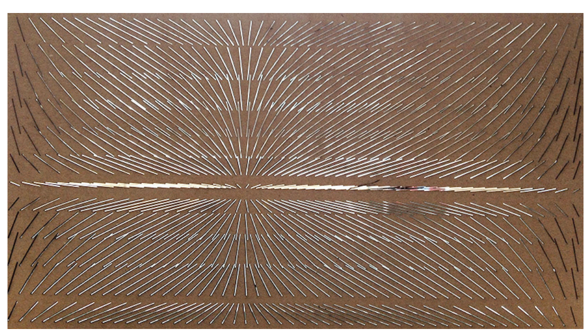

Fig. 10. Apartment Building Façade Screen, Reduced Scale (Photo: Spencer Hoyt)

How well did these projects enable students to engage technical parameters? The lamp project was particularly successful in this regard. Not every student achieved project resolution but there were significant discoveries regarding the congruence of conceptual and technical problem-solving. Moreover, students were particularly satisfied with their achievements on this project as evidenced by the work being featured in student portfolios.

One goal for this work is to demonstrate the wide-ranging forms and applicability of prototyping to enable students to integrate this practice into their own workflow at manifold scales and resolutions. To understand how well these projects succeeded will require tracking students through successive studios. Reflecting on this future integration, one student wrote at the end of the course,

> "As elements of my workflow, exploring fabrication, material, and scale have each yielded unexpected results, and added layers of richness that my studio projects have lacked. Looking forwards, the challenge is to find opportunities to integrate these lessons into my overall design process by finding time to work at this level of detail in my studio projects, either through sourcing actual examples of intended materials or fabricating small moments that are representative of larger schemes."[18]

For beginning designers, it can be difficult to advance studio projects beyond initial schematic design. Through this course, prototyping practices transcend the idealized digital realm for the contingencies of physical space positioning beginning designers to imaginatively engage technical parameters.

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Notes

[1]American Institute of Architects, *Architecture Student's Handbook of Professional Practice*, 14th edition (Wiley, 2009), p.332.

[2]Bob Sheil, "Design Through Making: Introduction," *Architectural Design* 75, no. 4 (August 2005): p. 7.

[3] Tom Kelley and Jonathan Littman, *Ten Faces of Innovation* (London, England: Profile Books, 2006), p.43.

[4] Kelley, *Ten Faces*, p.43.

[5] Scott Berkun, "The Art of UI Prototyping," accessed January 31, 2014, http://scottberkun.com/essays/12-the-art-of-ui-prototyping/.

[6] Berkun,

[7] Kelley, *Ten Faces*, p.43.

[8] Matt Franks, "Physical Prototyping" (Austin Center for Design), accessed January 3, 2014, http://library.ac4d.com.

[9] Berkun.

[10] Kelley, *Ten Faces*, p.55.

[11] Michael Stacey, *Prototyping Architecture* (Cambridge, Ontario: Riverside Architectural Press, 2013), p. 5-6.

[12] National Park Service National Historic Landmarks, "Program Adminstration Building and Research Tower Statement of Significance," accessed January 31, 2014, http://tps.cr.nps.gov/nhl/detail.cfm?ResourceId=1521&ResourceType=Building.

[13] The 2011 Latrobe Prize report entitled "Wisdom from the Field: Public Interest Architecture in Practice" describes how increased participation in public interest design has created a need for practitioners to cultivate new skills and strategies to support their expanded professional roles to meet the needs of these types of projects.

[14] Mark Burry, "Homo Faber," *Architectural Design* 75, no. 4 (August 2005): p 34.

[15] Nayef Mudawar, course reflection, April 2013.

[16] Tom Forker, course reflection, April 2013.

[17] Jason Danforth, course reflection, April 2013.

[18] Jason Danforth.

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