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Technical Provocations: Material Inventions, Structural Assemblies, and Environmental Responses as Precursors and Design Prompts

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Introduction

In most architectural educations, building technologies and design studios are taught as separate sets of courses where neither may fully impact the other until the design student is immersed in an integrative[1] studio. When technologies and design are addressed as separate lines of study, the concern is that students start to think of building technologies – materials and construction methods, structures and environmental systems – as disciplines that are considered after the design proposal is determined. Or students, particularly those who do not have significant experience in professional practice, can get overwhelmed by trying to consider all technology issues and design at the same time. Emphasis needs to be place on building technologies as impactful design determinants that can instigate and inspire innovation in architectural design.

This suggests a tighter overlapping relationship between technology disciplines and design curriculum. The technical application must then play a primary role in the construction of the studio design project and in the design of the learning experience. In our architectural curriculum, the integrative studio occurs in the second semester of a Two-year Master of Architecture program (Advanced Graduate Studio 2). In preparation for this integrative studio semester, we have developed and implemented an Advanced Graduate Studio 1 course that examines each building technology as the project design provocateurs. This strategy takes each of the following technology topics: materials and construction methods, structures, and environmental systems, as the focus of three separate projects in order to investigate the conceptual design potential of each discipline.

In typical studio design projects, students are given a program and a site and they design from the large scale down to the small scale. This means determining building forms first before considering infrastructure and detail. Instead, we approach the semester in the opposite directions. We start with the design of a full-scale fragment of a wall or ceiling that captures light but is driven by studies on materiality and assemblies. In the second project, we zoom out to the 1” = 1’-0” scale where structures are addressed at three scales of the building, the wall assembly, and the detail component. In the final project, students must design two small buildings that are designed for two extreme climatic conditions. In these three projects, we implement a conceptual understanding of building technologies in design studios so that the technology disciplines have greater impact in the design process. We were not concerned with specificities in each building technology discipline that would be addressed in their technology courses. Our objectives were to use principles of building technologies as primary motivators for design projects and consequently, to reveal the interconnectivity between these disciplines in hopes of increasing a student’s understanding of the role of infrastructure in integrative design.

The projects for this Advanced Graduate Studio 1 course were developed and first tested in the Fall 2015 semester by two professors who co-taught the graduate class of 28-36 students. We have taught this course curriculum for four years and in each semester, we have been adjusting and refining the projects in order to improve on results. This paper discusses the projects' processes and the issues and problems we encountered in this studio course. Due to this paper's word count limitations, we will refrain from going in-depth regarding the theoretical framework for each project in the studio course.

P1: Meditation of Light and Meditation on Matter

In architecture, matter is the medium through which design ideas become reality. Materials shape spatial experiences and architectural form. In professional practice, architects rarely get their hands dirty in the construction process. Instead the role of the architect during construction is to observe and note if the work is being built as per the design documents. In most innovative architectural practices, material considerations are integral to conceptual ideas from the start of the design process. To investigate and communicate material concepts, they proactively fabricate their own full-scale material studies during a project development. This effort ensures that contractors understand the design intension and also demonstrates how the assembly can be built.

Young designers entering practice often experience a gap between their design intentions and built reality. In order to minimize this distance, it is critical to engage matter hands-on to know its characteristics (weight, dimensions, limitations) and its relationships to other materials (joints, intersections, adjacencies). In this project, we address this issue head-on by designing at a 1:1 scale to investigate the impact of materials and assembly on design intention and the design process. The hands are challenged to tackle the physical and intellectual resistances of working directly with full-scale building materials. The goal is to develop a "seeing hand" that understands the relationships between architectural constraints and material realities. Instead of starting with the design of a whole building, we start with the detail in order to explore issues of tactility, phenomenological effects, and the poetics of material assemblies.

Working at full-scale with their hands, students develop a haptic knowledge of materials and the possibilities in the fabrication processes. There are physical implications with each material choice, so this project intends to also foster flexibility in design thinking. In a construction assembly, building materials are not equally interchangeable. In professional practice, design proposals are often adjusted and reworked through numerous iterations. An initial design proposal may be conceived as a brick building, but then other factors, including cost and availability, may alter the material choice which consequently impacts the design intention. Integrative design requires the seeing hand and the flexible mind in order to reduce the gap between intention and actuality. Throughout the project, we had the students read Marco Frascari's "The Tell-the-Tale Detail', Vittorio Greggotti's *Inside Architecture*, and Giuseppi Zambonini's "Notes for a Theory of Making in a Time of Necessity."

The Full-Scale Drawing

In the first week of the project, each student created a full-scale drawing that captured a design intention for transmitted or regulated natural light. The drawing, with a minimum of 6 feet in one direction, is scaled and positioned in relation to the human body to understand the experience of the light condition (Figure 1). The two-dimensional elevation drawing is understood as part of an implied larger design project. It is a fragment of a façade/interior wall, a roof/ceiling or a corner condition. The program for the drawing is the transmission of natural light, so the students must invent light qualities and the implication of material qualities like textures, color, and three-dimensionality through shadows. The full-scale drawings need to capture dynamic light and not just a static moment in time.

Figure 1. Full-scale drawings of invented light conditions. (Elizabeth Cronin, Sara Vecchione, Fall 2015)

The drawing not only communicates dynamic light and shadows but also reflects exterior and interior conditions. By seeing thorough the enclosure, it creates an implied depth and design intention in the spatial assembly, Within the drawing, students were asked to address scales of information – underlying grids and repetitive elements or texture. The drawings expressed materials and assemblies (seams, overlaps), design intent (narrative, experience), a range of scales (fasteners, surface texture) and measure (proportion, underlying systems of organization).

We encouraged students to avoid the typical window aperture. The drawing had to consider the orientation of the sun and the shaping or forming of light regarding its quality, color, texture, grain, and scale. The drawing explores the construction of an apertures and a wall fragment that lets in light but also whether the fragment allows, denies, or directs views outward. Students could use any media of their choice, but the drawing could not be a continuous sheet of paper. It had to be constructed of at least two pieces so that the full-scale drawing itself was a physical construction. The connection between pieces had to be intentional and meaningful in the drawing.

The Material Experimentation Laboratory

In the following two weeks, the students zoomed into details of the big drawing and experimented with material studies that resonated with their design. For each detail, they would compile a list of possible materials and the processes of working with those materials to achieve their lighting effects. For instance, in Figure 1, the textures and light in green could be made of oxidized copper, fritted tinted glass, concrete reflecting green light, etc. Qualities of transparency, translucency and opacity are vetted in the full-scale drawing.

Our graduate students functioned as a collaborative for this portion of the project. They could work individually or in teams but all their material experiments would be compiled into a materials library for the whole class. Students with similar interests in casting concrete would work together to cover more ground in experimentation and build a larger body of empirical research. The material studies were full-scale and could not be made of representative materials or found objects. The experiments had to be serial in nature to explore a range of possibilities and to investigate connections between materials through research on joints, attachments and anchors. Serial studies are critical in this experimentation process; one material sample does not provide enough information to determine the design intent. The students were asked to empirically interrogate material results and to constantly ask “what if” to determine their next steps. Daily group discussions encouraged the students to engage in more innovative approaches.

At this stage of the project, we also ask the students to speculate on how various material options would affect their original design intentions. Since they are making and working with materials with their hands, learning to use fabrication tools, and refining their techniques to build with precision, it is easy to forget what were the original design intentions. We constantly refered to characteristics in their full-scale drawings in an effort to maintain their awareness of their conceptual ideas.

The Full-Scale Assembly

In the final two weeks of the project, each student decided on materials and proposed an individual 1:1 scale assembly that resonated with their original design proposal (Figure 2). The assembly must be freestanding and address an interior and exterior face. Representative materials were not allowed. During the previous weeks, the students concentrated on the small-scale details. Now to build a full-scale construction, they were challenged to address armature or structure to support a free-standing assembly. Students were permitted to engage local fabricators and they were encouraged to look beyond the big box hardware stores. The final constructions are placed outside for the rest of the semester, alongside their original full-scale drawings, so that we can discuss effects of weathering and their lessons learned.

The issues we encountered in this project stage was many of the assemblies were more like sculptures than wall assemblies. The two-week time frame was too quick and in desperate attempts to finish, students rushed their constructions and left out critical components. Another limitation was that students had to fund their own constructions so issues of cost had a huge impact. In the Fall 2016 semester, the 2015 NCARB Award provided substantial funding for this project and we were able to help subsidize the cost of the students' constructions. We address the issue of material waste by requiring that students must use mechanical connections in their assemblies. At the end of the semester, we disassemble their 1:1 scale construction and save materials for next year's graduate class to use. This also helps to reduce the cost for the students in the next year.

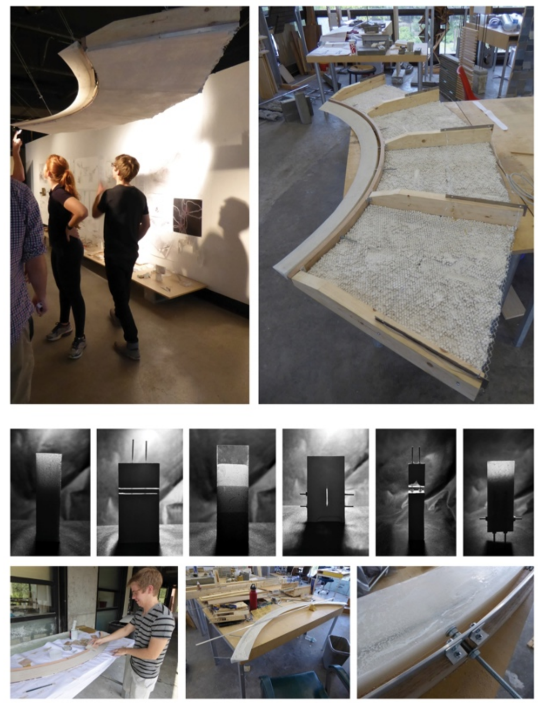

Figure 2. Testing and building the full-scale construction. (Nick Johnson, Fall 2015)

At the end of this project, the most common comment from students was 'it didn't turn out the way I thought it would" which was our motto for this project. This project intentionally embraces failure as a strategy to heighten awareness of the gap between design intention and final construction and the role that materials and construction processes play in the final results. In the lessons learned discussion, the majority of the students were very alert to how they would approach the project if they were to do the project again.

P2: Spatial Intersections

The first project of the semester was rooted in 1:1 material exploration and shaping assemblies in the service of light and space. Whereas Project 1 was framed as a singular moment occupied by a singular authorial occupant, this next project required a consideration of multiple occupants, adjoining and related spaces, and issues of dynamic light, time, and movement. In integrative design thinking, we must acknowledge that structural systems exist at three scales: of the building, of the assembly, and of the component. In Project 1, structure is addressed at the component scale in supporting the materials and the wall fragment. As we focus closer from the building to the detail, we see that every part of the building has structural support that relies on the larger primary structure. In Project 2, students situate their 1:1 scale light and material construction within larger spatial conditions. For the next three weeks, they work at a 1'=1'-0" scale to examine the effects of primary structural systems on their design intentions.

We zoom out to consider Project 1 in the context of a larger fragment of a building space or a spatial interlock between two or more spaces. The students start by determining a primary structure that would shape the building spaces. The larger structural system comes to the forefront. In the full-scale material construction, the students build a structure that is at the scale of the wall or roof assembly. This larger structural system provides overall spatial definition for the building and it must work in conjunction with the material assembly and the control of natural light. The first question the students address Is where primary structure sits in relation – in front of, flush with, hidden within, or up against - their enclosure fragment. At the same time, they also explore the material considerations for the structure and the effects it has on the design intention. They know the quality of light and material conditions for their design but now it was to be design in conjunction with structural implications.

The students design the building fragment through partial plans and sections, axonometric projects, and 1'=1'-0' scale physical section models. The full-scale building materials from Project 1 are now addressed at representative scales so the students are challenged with using representative materials to capture materiality in the physical model (Figure 3). The size of the physical model is critical because of its direct association with the typical scale of building details drawn in professional practice. The physical models needed to be large enough to delve into the assembly and the component scale of structure while also small enough to be manageable for a student to build in three weeks.

Figure 3. Drawings and 1'=1'-0' scale physical models studying structural systems in their design work. (Anggitta Nasutation-Zurman, Fall 2015)

The issues we encountered were fundamental – preliminary struggles with logic and rules-of-thumb for spacing and sizing structural systems. The majority of our students had studied structures as a course isolated from design studio and it was clear that there was a disconnect in how structural applications are integral with design intentions and decisions. The students were accustomed to incorporating structure as an afterthought.

P3: Between Ground and Sky

What we build and how we build are closely tied to the sites and places in which we work. Site informs material selections, formal responses, tectonic assemblies, and structural solutions. A careful understanding of ground is critical in determining how best to touch, engage, mark, or shape it.

When we engage the physical world outside the studio, site and landscape become more than passive tableaus or inert media within which we operate. The natural landscape is, in fact, a complex and nuanced field marked by overlapping and competing systems. Networks of plants, animals, and insects feed, consume, and interact with one another. These living communities are dramatically affected by factors that define the climate of a region, including seasonal variations in light, precipitation, and/or temperature.

When we consider the human condition within these natural systems, there are a number of new issues that arise. Issues of culture, history, belief, social structures, psychology, reason, passion, and memory enter. In one extreme position, all of these issues dominate and overshadow all other concerns, often resulting in fragmented habitat and interrupted ecosystems. At another extreme, the human is identified as fundamentally "non-natural," excluded from participation in these systems and from occupation of certain places. Between these extremes, there is the opportunity to recognize the human as an active participant in environmental change, positively interacting with changing natural systems.

To work in this way requires simultaneously considering both the human condition and the sites that we occupy, reading both to discover and uncover aspects about them that may not be readily legible. In this last project, we encouraged students to begin to recognize personal attitudes but also learn to meter their impact on their work. The objective of this project was for the student to develop a sensitivity to the places and climates in which they will work in the future. This requires them to distill spatial conditions that transcends their own preferences and become meaningful to others.

In this project, students map and quantify certain aspects of a site, searching for traces of changes that have occurred over time, patterns in vegetation and/or wildlife activity, changes in topography, ground-cover, and soils. This part of the work also engages solar movements, wind, water, and time. Diurnal changes in light, temperature, and humidity intersect with longer-duration seasonal shifts in precipitation and annual fluxuations in temperature.

The first two projects of the semester aggressively engage the issues of light, materiality, joint, assembly, enclosure, structure, and program. The third and final project of the semester brings all of these issues together with the issues of ground, sky, water, and place. However, the work from the first two projects were not necessarily carried into this third project.

Analyzing Site, Climate, and Precedents

For the first two weeks of the project, we focused on climate and precedent studies. In identifying sites, we used maps based on the Köppen-Geiger climate classification system. This system, developed by Wladimir Köppen (1846-1940) and Rudolf Geiger (1894-1981), is the most widely used to classify the climates of places on our planet. It is based on general temperature profiles, latitude, precipitation, and vegetation.

In this project, each student designs two small projects that will each occupy sites in two different extreme climates: hot and cold. To be more precise, they operate within zone A ("humid equatorial climate") and zones D-E ("humid cold climate" or "cold polar climate"). Within these broad regions, the students divided into teams to research these two climate zones in more detail. At the same time, each student chose one building precedent in each climate zone to analyze.

The climate research focused on specific locations within the selected zones so that the students studied how those places deal with the extreme climatic conditions. The students' research included, but was not limited to, weather patterns, thermal comfort requirements, sun exposure and orientation, and traditional and regional materials and methods of construction.

The precedents research and analysis looked at contemporary approaches to building in these extreme climate zones. The students could compare traditional strategies with more recent strategies to understand changes in technology or methods of operation. The research for climate and precedents was presented and then compiled into a single document as a resource for the studio

Designing in Parallel Two Projects in Extreme Climates

Following the climate and precedent research, the students have five weeks to develop two projects which focused on the construction of a joint, moment, or threshold within a cold polar climate and a humid hot climate (Figure 4). Each project was no more than 1000 square feet of enclosed area. Students had the freedom to choose their sites and they could invent the program for each building. But they had to engage and respond to the particularities of site and the environment, specifically mitigating all forms of water and variable climate conditions.

We focus on environmental technologies in terms of passive strategies and developing a sensitivity to regional conditions and the methods of addressing climatic issues. The two extreme climate zones are design prompts that set up oppositions in almost every aspect of designing a building – the composition of the wall assemblies, the form of the roof, the way the building

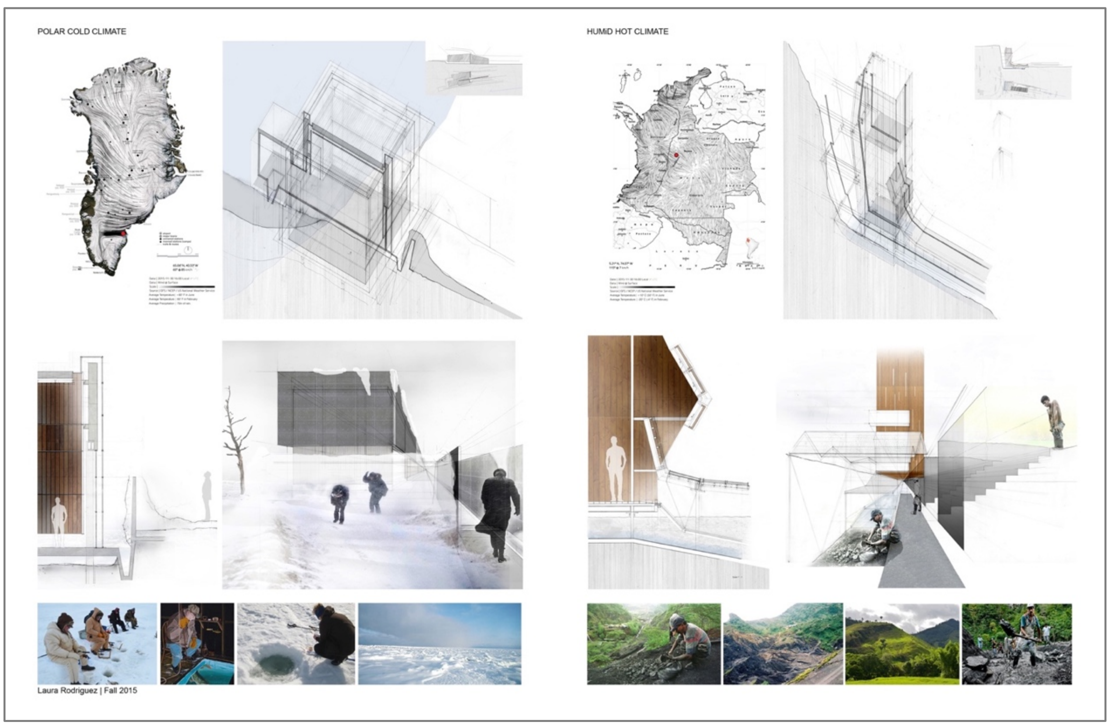

Figure 4. Project studies in the polar Cold and humid Hot climate zones.. (Laura Rodriguez, Fall 2015)

touches the ground. Since these two projects are designed in parallel, it heightens the student's awareness of how differences in climate affects the building design.

The students had the freedom to choose formats and media in developing these projects. This gave them an opportunity to determine their own design processes and to be more specific about their research interests. The character of the place and the distinction between the two projects had to be visually clear in the work. Because the two projects were in contrasting climates, they would have very apparent differences in the designs. Their two projects did not need to be related to one another, but the projects had to be designed in dialogue with each other.

In this project, students zoom out to investigate the buildings as a whole, but also the building as a fragment within a place. Interestingly, the most prominent issue that emerged from this project is that the students, most of which grew up humid hot climates, had a really difficult time comprehending cold weather. Most of them had never seen snow. Despite their research on polar cold climate zones, designing for extreme cold climates was a foreign concept to many. Our original objectives asking the students to step away from only thinking about their own experiences and focus in on how the building must react and respond in its climatic locations.

Conclusion

In all three projects, one of each building technologies takes on a leading role in prompting conceptual design ideas. But inevitably, the other technology disciplines also fold into the projects due to the interwoven nature of infrastructure in buildings. These projects try to explore how building technologies are not just practical issues to address or to integrate after the building design is determined. But instead, they can have conceptual meaning and influence in architectural design. The three studio projects concentrate on the conceptual design realm and not precisely in pure professional practicalities. This is primarily to present to the students that the principals of building technologies can be employed as conceptual design factors and to encourage architecture that is designed with a sensitivity to technology matters.

It is critical to maintain conceptual and abstract design ideas in the integrative design studios. We are concerned with students losing a sense of conceptual thinking in their design work if the technologies are brought into their projects only as practicalities.

Now that we have four years of implementing this curricular strategy, in our next steps, we would like to take a closer look at the effects from this curriculum and to examine whether this curricular strategy is effective as a precursor to the integrative studio and in the students' professional practice experience. We are interested in interviewing the students who have graduated and continued in professional practice for their feedback and thoughts on the course. We are hopeful that our curriculum is meaningful and that we can continue to develop this strategy to greater effect.

Acknowledgements

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Notes:

1 As defined by Item C.1 in Realm C: Integrated Architectural Solutions in the Student Performance Criteria of the *NAAB Procedures for Accreditation 2015 Edition*.