Techne: Teaching Iterative Tectonics to Architecture Students

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ABSTRACT: *A work of architecture is made of numerous components and learning how to use these elements to communicate ideas gives designers agency to enrich their work. Becoming engaged in how buildings are made and exploring how to assemble materials is a critical opportunity for architecture students, one that might help them to develop a tectonic language informed by critical exploration. Nathaniel Coleman articulates the opportunity and concomitant challenges: "Architecture is not as nuanced as language; its elements are expressively more limited but potentially more immediately powerful. Architectural elements including materials, details, and forms constitute a series of hieroglyphic characters available for a kind of physical writing that through use speaks directly to the body. More explicit links between architecture and language could take shape at those junctures where material and form analogize some describable social idea. Here, social is intended to encompass individual and group experiences of being in the world, individually or collectively, from the uprightness of a body to the character of a community. The difficulty modernist architecture has in locating points of intersection with language arises, at least in part, from the tension between exaggerated individual artistic expression in one direction and trivial practice in the other, with both dominated by a more than less universal building industry that demands standardization."*

The University of Arizona School of Architecture created a course called Techne to provide second year students the skills needed to support their studio education. The course was intended to integrate digital modeling, shop skills, photography and image management, and other skills. In the current incarnation, we were given the opportunity to focus the skills training on improving students' ability to use material exploration as an iterative tool that could inform learning digital tools, and to help students to learn to move between digital production and physical fabrication, leading students to learn tectonics through the creation of both physical constructions and digital analogs.

Teaching tectonics is a process, one that requires the instructor to focus on the methods of fabrication and construction at the beginning of any project. Formal exploration, the normative approach of most design courses needs to follow considerations of material assemblies. This does not preclude formal innovation, but it is essential to foreground the materials and methods of construction. As Edward Ford states in The Architectural Detail:

My sense is not that joints are necessary for construction, but that they are necessary for coherence, for architectural meaning to occur, even if jointlessness is technically feasible. It is clear that long before the modern era, the understanding of the parts of a building and their constructional relationship was a key to a larger understanding of the building as a manifestation of ideas. The assembly of parts in precarious equilibrium can be understood as a parallel for another system: a social order, a political order, a philosophical order, a natural order.1

KEYWORDS: teaching, pedagogy, hands-on learning, tectonics

THESIS

A work of architecture is made of numerous components and learning how to use these pieces to communicate ideas gives designers agency to make their work better. By learning more about how buildings are made, and how they can be constructed, architects can create more design opportunities. Becoming engaged in how buildings are made and exploring how to assemble materials is a critical opportunity for architecture students, one that might help them to develop a tectonic language informed by critical exploration. Nathaniel Coleman articulates the opportunity and concomitant challenges:

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How might we teach students to understand tectonics, and how to value it as integral to the design process? It is precisely this tension between the polarities of standardization and artistic expression that we intend to explore. Much of the agency architects have begins with developing a critical response to these competing imperatives. We have developed projects to show students that they can design and make many more things than they think, and these opportunities can help students to create compelling architectural interventions. The iterative processes we created helped students to understand the development of tectonic principles.

CONTEXT

The University of Arizona School of Architecture created a course called Techne to provide second year students the skills needed to support their studio education. The course was intended to integrate digital 3D modeling training, shop skills, photography and digital image management, and other techniques. In the current incarnation, we were given the opportunity to focus the pedagogy on improving students 'ability to use material exploration as an iterative process that could inform learning digital tools, and to help students to learn to move between digital production and physical fabrication, leading students to learn tectonics through the creation of both physical constructions and digital analogs.

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Design build is a well-established pedagogy for teaching tectonics. While the details differ considerably from one university program to the next, design build studios typically design small projects (very often a small house), and then build the project themselves, sometimes with a few key subcontractors depending on local regulations. Students learn everything from creating construction documents to nailing wood framing members together, but the most important lesson is how to understand the complex order of operations and interrelationships that make up every architectural project. This process is extremely valuable to the student' education, but it is limited in its application due to logistical challenges, not the least of which is that students often need to learn the basics of design and construction before undertaking a design build project. This usually results in these studios being scheduled near the end of a school's curriculum. As an academic engaged in design build projects for the past decade, the author is keenly aware of these limitations. How might we begin teaching students these fundamentals using hands-on techniques earlier in their education? Kenneth Frampton illustrates a potential approach:

> The one tends towards light and the other towards dark. These gravitational opposites, the immateriality of the frame and the materiality of the mass, may be said to symbolize the two cosmological opposites to which they aspire: the sky and the earth. Semper's emphasis on the joint implies that fundamental syntactical transition may be expressed as one passes from the stereotomic base to the tectonic frame, and that such transitions constitute the very essence of architecture. They are the dominant constituents whereby one culture of building differentiates itself from the next. There is a spiritual value residing in the particularities of a given joint, in the "thingness" of the constructed object, so much so that the generic joint becomes a point of ontological condensation rather than mere connection. We need only think of the work of Carlo Scarpa to touch on a contemporary manifestation of this attribute.[2]

We began to think about the fundamental differences between cast and tectonic materials in the models the students might make, and how this informs students 'thought processes. Frampton's articulation of the fundamental difference between stereotomic and tectonic elements formed the generative pedagogy that developed into our approach to teaching second year students. In addition, a fundamental questioning of typical architectural practice—design then fabricate precisely to match—became a key component of the pedagogy as it was developed.

> Scarpa's re-working of the conventions of drawing might encourage us to similarly position a way of thinking and constructing that also breaks out of the rigid confines of representation. This might be akin to sketching with material—working at full scale, responding to the conditions, resistances, and tolerances of actual materials, searching for the latent and serendipitous rather than being bound by an abstract set of explicit instructions. Must a constructed architectural artifact always be the material consequence of a pre-determined idea—fixed and delineated by someone and then constructed by someone else—or can the act of making itself be generative, exploiting the dense, fertile ground of difference that Evans is implying and that Scarpa demonstrates in his drawings? I propose a way of building that uses the transitive power of iterative prototyping to advance the tectonic qualities in the work. This is not simply to say that the architects' involvement in the work is any guarantee of success—only to suggest that the gap between the abstraction of drawing and the constructed outcome has been neglected as a source of inspiration and meaning. A robust period of material and assembly explorations, full-scale prototyping, testing for fit on site, all

> combined with simultaneous refinements and modifications, constitute a significant part of a holistic and empathetic design process that has somehow disappeared in the work of most architects.[3]

METHODOLOGY

Techne begins with students learning how to use the shop by making a series of predetermined wood block shapes, which are used to create simple, speculative massing model arrangements. Students developed design skills, utilized narrative, two-dimensional computer drawing, photography, and sketch overlays as design and representation tools.

The students were tasked with composing eye-level photographs, which are used to describe verbal prompts. These prompts serve as context to inform Photoshop texture mapping exercises. Students were asked to create an Open Courtyard, Terrace with Access, a Series of Multi-Level Units with 3, 5, and 7 blocks, and an Open category, totaling 10 models. Students then created their first Rhino 3D models based on the block massing assignment.

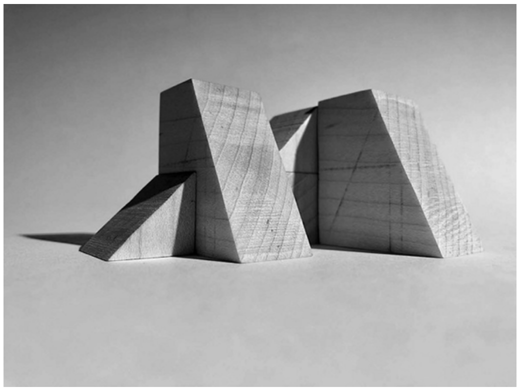

Figure 1: Wood Block Massing Model. Source: (Anthony Rascon, Student 2021)

Figure 2: Photoshop Material Study. Source: (Anthony Rascon, Student 2021)

The objectives of this assignment were to develop representational skills in physical prototyping, digital drawing (using Rhino 2D), as well as design skill in abstraction and observation. Students learned basics of 2D drafting, liveweights, layers and printing, and demonstrated ability to document their projects using architectural conventions. They also learned how to photograph architectural models to communicate ideas regarding proportion, daylight/shadow, and to convey narrative ideas. They also began speculating about how materials might be used early in the design process, by applying texture maps to their massing models via Photoshop, allowing rapid exploration.

In the next phase, the class began creating small cast explorations using rigid insulation foam as form work. These gradually increased in size and complexity, ultimately leading to a full-scale detail component cast using concrete with reinforcing rods and conventional plywood formwork.

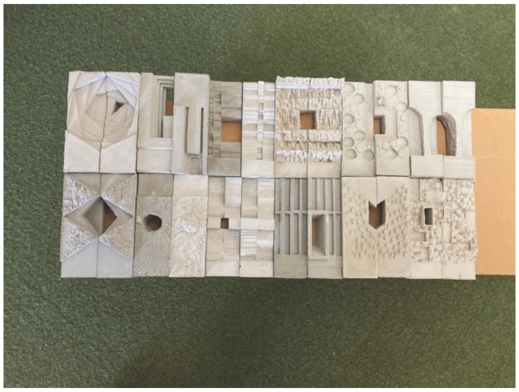
Figure 4: Preliminary Cast Material Studies: Surface+Opening. Source: (Author 2021)

Students developed their designs through experimentation and iteration, using digital and physical modeling to create modular cast models that explored surface textures and openings within the surface. These explorations included fundamental principles of architecture to include repetition, solid/void, contrast between surface textures, and numerous other potential discoveries. The objectives of this assignment were to develop representational skills in physical prototyping. Students learned how to make well-crafted models and developed understanding of the value of iteration. Many cast elements required refinement, but open-ended experimentation resulted in numerous discoveries. They also learned the reflexive relationship between physical and digital modeling and utilized these skills to inform the creation of the cast modules. The process of making, reconsidering, and re-making led to highly refined results, often with unexpected outcomes students would not have achieved otherwise.

Parallel to the increasing casting scale, students were expected to carefully photograph their projects. One of these photos was developed into a photomontage that shows shade, plants, and the addition of a framed opening to result in the appearance of a completed building. Creating this composite image was a somewhat convoluted process, but one that taught students a number of skills that they might not have explored otherwise. Incorporation of the plant and plant shadow in particular were steps that gave students the opportunity to develop skills with wider opportunities for further development.


Figure 6: Surface+Opening Composite Photomontage. Source: (Alexio Mora, Student 2021)

The first step was taking photos of distinctive native Sonora desert plants, and then using Photoshop to carefully crop out and isolate the plant profile. The cropping border was then transferred to Rhinoceros as a continuous, closed polyline, where it served as a laser cutting profile. These profiles were cut from thin chipboard, and then used to cast the desired shadows onto the concrete cast models, which were then photographed, making sure the profiles were not visible in the photo. The final step was to insert the cropped plant photo as a layer into the cast project photo, carefully aligning the image to the shadow, creating a convincing composited image. Creating the appearance of a window was fairly straightforward by comparison, students were shown how to add a gradient across a specific area, then added another layer with an outdoor scene which is made transparent. Once these two layers are superimposed, it gives a reasonable impression of glass reflections. These techniques can be implemented quickly, providing a more realistic impression for the overall composition than one might be achieved with rendering software, especially regarding the textural richness of the cast components.

The projects are intended to help students to explore material culture, and to lower barriers to entry and iteration. Our pedagogy actively encourages iteration, by teaching students to play with materials to see what they can do. Engaging students in the essential value of iteration was a focus of the work throughout, but we made this explicit in the second semester. The second semester focused on assemblage of framed, tectonic elements, in Frampton's terminology, in contrast to the stereotomics of the fall course.

In the Spring semester, the first assignment required students to duplicate the construction of a wood 2x4 framed wall assembly exactly as prototyped by the instructors. The purpose was to start with a measurable, verifiable project; students would either build theirs correctly or not. It was important that students could not explain away something that was not square and true. Objective criteria were intended to demonstrate to the students that this was achievable, even with beginner's skill levels. The project also required paying attention to the order of assembly.

The next step was to use standard 1x2 furring members to develop a horizontal composition spanning across the frame wall. Student teams were required to use either 4'-0" or 2'-8" lengths and spacing between members were required to be increments of the actual 3/4 or 1-1/2" dimensions of the nominal 1x2 members. Students attached the members with a brad nailer, allowing quick attachment as well as removal as required. They were allowed to place the furring members with either the long or short dimension placed vertically. While the number of constraints might seem to severely limit opportunities for creative expression, the resulting projects prove otherwise.

Figure 8: Cladding-Layering Iteration 1 Examples. Source: (Author 2022)

We deliberately set up many constraints in the exercise, trying to create as limiting an approach as possible. Despite this, each project became vastly different from each other.

"Design depends largely on constraints."[4] Charles Eames' dictum explicitly informed our pedagogy and was critical to student success. It is precisely the degree of constraint that helps designers to understand the nature of a design problem. The more constraints, the clearer the solution.

The students were required to create Rhino models of their work, which were used as part of the next iteration of the project. Part Two required the students to create a 16" framed corner section and add it to the existing frame, and then explore how the students' compositions might "wrap" around the corner. Exploring how materials transition from one geometry to another is an essential part of the art of building, so students were confronted with the opportunity to create their own point of view on how to articulate the corner condition in their projects.

For this part of the project, students were given the same 4' and 2'-8" length requirements, and students were expected to add a second layer to their screen assembly. The implication was that this layer would be primarily vertical, but this was not explicitly stated. Because all the teams had some of their horizontal members in different orientations, the surface was not flat, which affected the resulting compositions. Another detail that became quite significant in some students' projects was that in adding the second layer to the project, we gave the students the option to use either brad nails as they used for the first layer, or countersunk black oxide coated wood screws, which create opportunities to provide a highly visible method of attachment in contrast to the nearly invisible brad nails. This contrast was used to contribute another ordering layer in some projects.

Figure 9: Cladding-Layering Iteration 2 Examples. Source: (Author 2022)

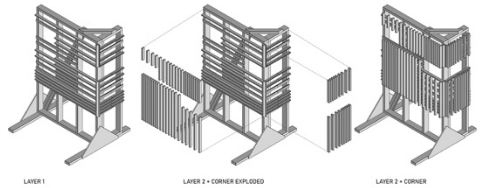

Figure 10: Cladding-Layering Process Drawing. Source: (Emme Mooday, Damien Narum-Brelay, Andrew Rodriguez, Linea Skura, Student Team 2022)

Figure 11: Cladding-Layering Iteration 2 examples, one with screws creating an ordering system, one without visible screws. Source: (Author 2022)

Interestingly, many of the students seemed resistant to actively engaging the corner, especially with layer two. Specifically, they resisted creating another, fully developed second layer, but when they began utilizing iterative rhino model studies and sketches, they began to become more engaged with the opportunities this project presented. While some students seemed to resist the iterative process initially, they eventually embraced the challenge, and their work developed significantly. Several teams embraced unexpected, accidental discoveries that occurred due to lack of experience in assembly processes. These in turn informed their computer models in a reciprocal relationship that improved the design process. In Figure 9 above, the students inadvertently attached the angled components at the bottom first, resulting in these parts rotating at an unintended angle. This unexpected discovery resulted in a more interesting relationship of parts, something that likely would not have happened if the project would have been designed entirely via computer, and then fabricated exactly per the preconceived design.

Part 3 of the project required students to create a framed opening. The shape was initially defined by existing frame member locations; students were told not to cut any of the primary structural frame members. Students were given one piece of 24-gauge steel, 12x48” with which to create the frame; the material could be cut, folded, and attached as necessary to create the framed opening. Depth and height were not constrained, except by material quantity.

Students were provided cardboard which they used to mock up their solutions, while simultaneously working on 3D computer models. Each student team member developed one option, and then the team compared design ideas to determine how to proceed with the group solution. Later, they developed laser cut templates using chipboard; the laser cut patterns were derived from the students' Rhino models. The shop's laser cutter has a 32" maximum size, so students were required to use maximum pattern sizes of 16"Wx32"H. Creating laser cut components facilitates students in developing an understanding of how the components fit together before creating the steel parts, a common practice in industry. Students learned to consider the assembly and attachment methods as integral to their design processes. The teams began to realize that there were numerous opportunities to extend their design ideas by taking advantage of the panel joinery and fasteners to emphasize their project's area of focus. There were several examples that demonstrated a further layer of communication through the fact that the project was made from multiple pieces. This recognition allowed for another layer of design ideas and a means of communication of these ideas. Many teams overlapped their pieces with assembly tabs on the outside of the box, to make sure the interior of the box was clear of visual distraction. Some teams also made mounting tabs that attached their boxes to the frame, keeping fasteners out of the interiors. One team went further, designing their assembly so fasteners would be invisible from inside and outside of the opening projection, resulting in a complex assembly process, but one that enriched the design development. These seemingly simple decisions are just a few demonstrations of the fundamentals of tectonic expression.

Figure 18: Frame-Opening Final Assembly with Expressed Fasteners. Source: (Author 2022)

Figure 19: Revised first semester final project demonstrating tectonic/stereotomic interrelationship. Source: (Author 2022)

RESULTS

The second iteration of the Fall course incorporated an early exploration of tectonic assemblies to form a counterpoint to the stereotomic/cast projects. After teaching the course sequence the first time, we determined that finding a way to create an explicit bridge between the first semester's focus on stereotomics and the Spring's tectonic emphasis was appropriate. With this in mind, we developed a short exercise using the students' previous castings as the site of additional exploration. The students were tasked with using small basswood members in two sizes to create a spatial assemblage to create pattern and shade in contrast to the cast elements; the students were expected to clamp, wrap, cantilever, and intersect their castings in unexpected ways due to the need to respond to the existing context, as seen in Figure 19 above. This results in many interesting relationships because the intersections weren't pre-planned. Students then re-made the casting to respond to the intersections between cast and tectonic elements. This process resulted in students creating richly expressive projects, and prepared them for the larger, more complex tectonic assemblages that followed.

The way we approached Techne is an argument in favor of Edward Ford's "The Detail as Join," one of the philosophical constructs articulated in his book The Architectural Detail. By intentionally making the students create the project in discrete phases, it required students to carefully consider the existing context, and respond to the actual parts that were present. This approach made it challenging for students to think about the project as a whole, and instead meant that students had to think about the specific components within their projects. This created numerous unexpected and challenging conditions, which in turn created opportunities for the students to further articulate their tectonic ideas.

Students have learned a number of technical skills and received essential reinforcement of the importance of foregrounding the means and methods of assembly to architectural production. They have also demonstrated the importance of working between digital and physical iteration, as experimentation is beneficial in both realms. The studio faculty have taken advantage of the students' newfound abilities, most directly with their facility in creating cast models. It remains to be seen whether their other skills will be integrated into studio teaching.

CONCLUSION

Whether it was a moldy melon leading to the discovery of penicillin, or Marcel Duchamp's "Large Glass" being inadvertently cracked during transportation to an exhibit, accidental discoveries have a celebrated history of transformation in the arts and sciences. The accident can be more informative and interesting than the intention. Because computer input is determinate by design, it is at times challenging for architecture students who use conventional digital design tools to make unexpected discoveries as they work. One would have to find ways to subvert this tendency, an interesting possibility for faculty with greater digital design expertise to explore.

Hands-on, skills-based teaching has set Techne students up for success in future classes, especially the design-build studio. Having said that, even if students never create another physical prototype again, they will have learned the value of iteration and moving between different modes of representation, skills that will serve them well as they continue their architectural education. The methods of teaching demonstrated here can be readily applied in other programs, although the biggest challenge will likely be getting the class itself approved as separate course sequence. Many faculties may think these skills could be incorporated into their regular studio sequence, but without a formalized pedagogy that makes room for focused, skills-based learning, it would be challenging to integrate the lessons demonstrated in this paper into a cohesive and effective experience for the students.

ACKNOWLEDGEMENT

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END NOTE

[1] Edward R. Ford. The Architectural Detail. (New York: Princeton Architectural Press, 2011), 226.

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