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> The microscope and microphotography discloses a new world. They reveal, in this age of haste and superficiality, the marvel of the smallest unit of construction: our substitute for the longer period of time that primitive man could devote to observation (László Moholy-Nagy,)

Introduction

As educators, we want architecture students to not only gain a clear understanding of scale in design but also acknowledge that design operates at multiple scales. In this paper I will explore a pedagogy that initiates the design process in foundational architecture design studios by using the microscopic scale as a point of departure to develop a language of construction – or a tectonic language. I have been teaching architecture since 2004, and have been running studios that use micrographs as a point of entry to study architecture. As we enter a familar/unfamilar microscopic-scape, we can engage both the precision of observation and the spark of curiosity as a way to reveal and harness the magic in the everyday.

Background – Observation as an active act

The microscope allows us to use optics as a "mechanical eye" (Kemp, 2006) and peer beyond what is visible to the naked eye. As Lynn Gamwell observed:

> As Images of microorganisms made with an achromatic microscope became for the mid- to late-19th-century public what celestial images recorded by the Hubble Space Telescope are today: They offered an extraordinary sense of being transported to another scale — an exotic place tinged with danger, they were exquisitely beautiful, and they were reproduced everywhere. (Gamwell, 2003:49–50)

The microscope extends our perception beyond our own human scale, and in so doing, we may re-frame how we view both tectonics and the composition of our physical world. Looking beyond the threshold of human perception, we find that even surfaces that we consider flat and thin are made of complex structures. When we introduce this to students, we open an interior trapdoor so we can embark on "a trip into the thickness of things," that allows us to 'invade' their characteristics and expose them to new light (Ponge, 1945:14). This peering and observing allows us to harness curiosity and deepen our investigation, and scale is an essential aspect of this process. As architects, the immediate scale we consider in architectural education is the human scale, or scales that could be experienced through human perception. But

with the advance of tools of observation, we have acquired mechanical eyes much beyond our natural capacity to see.

In the film Powers of 10, Charles and Ray Eames take the viewer through a multi-scalar journey (Eames, 1977); as we magnify or retreat, we witness how principles of structure may be shared across scales. The Eames' gaze suggests a seemingly fluid transition between scales, a smooth equalizing journey. But the complexity of scalar transition is greater and escapes human control. In each scale, different environmental factors inform tectonic evolution in distinct ways. As Donna Haraway poses, using observational technology is understood as a highly specific and active act that constructs a world from its particular viewpoint:

> The 'eyes' made available in modern technological sciences shatter any idea of passive vision; these prosthetic devices show us that all eyes, including our own organic ones, are active perceptual systems, building on translations and specific ways of seeing, that is, ways of life. There is no unmediated photograph or passive camera obscura in scientific accounts of bodies and machines; there are only highly specific visual possibilities, each with a wonderfully detailed, active, partial way of organizing worlds. (Haraway 1988: 583)

Similarly van Dijck sees the interior gaze into the body as an active shift in perception and conceptualization, claiming that "every look into a human interior is also a transformation – 'seeing is intervening' – because it affects our conceptualization and representation of the body" (van Dijck, 2005: 8). When we adopt Haraway's active view as a way to begin to imagine an act of world making from our particular framing of values, we can use the microscale to shift our perception and conceptualization of the physical world. The microscale opens a lens to a world built by non-human forces, similar to Haraway's insights. We use this non-human lens as an instigator of our world building, bringing awareness to a larger context .

In this pedagogical approach, students begin their architectural studies by closely observing structures that make up the fabric of our world from a different perspective. Acknowledging that we cannot displace tectonics from the micro scale without adaptation, students examine microstructures through an act of translation and re-interpretation. By introducing a less-familiar mode of building, these scales broaden our ideas of the built world beyond a human-centric frame of reference. I do not suggest an automatic adaptation from one scale to the other, but rather an engagement in the process-based translation of observed spatial and structural principles into universal ones that allow a development of a tectonic system that may be deployed in an array of scales that respond to different programmatic agendas.

Method - Micrograph providing a tectonic model

Act one – The micrograph

Almost a hundred years ago, László Moholy Nagy wrote that studying the micrograph allows us to step away from haste and superficiality and observe the marvel of

the smallest unit of construction (Moholy-Nagy and Bauhaus, 2005). Today his comments still resonate loudly. We begin with a micrograph as an object of inquiry and spatial exploration. In some studios, the micrograph is a found object developed by others, and linked to a field of study, while in others the students actively create microscopic imagery of a three dimensional object, actively shifting their perceptions and preconceptions of the material world.

Students observe a world that is both foreign and familiar, one in which the structures are not human made, but observed and reframed. These structures are operating under different constraints and pressures at the microscale. At these introductory design studio levels we do not claim to fully grasp the ecosystem of parameters and factors affecting material makeup, but rather we use the microscale as a key to unlock an alternative act of world making. Students formally break down the image and the tectonic component, viewing the micrograph as a two dimensional composition as well as a three dimensional construct.

Act Two – Universal tectonic translation

> Pure vision shows us this original unity [of spirit and nature] as an enduring force in all things, as the universally shared force common to all things. This deepest universal element was termed by Aristotle substance – that which is the thing-in-itself, existing of itself, independent of those accidents of size, form, or qualities which constitute only the outwardness by which substance is manifested… If substance is the enduring force then a direct representation of the universal (or direct plastic expression of substance) is not merely justified but required. (Mondrian, 1917:48)

Mondrian adopts an Aristotelian approach where ideas contain qualities that are beyond scale and can abstractly manifest plastically. In our design process we use language to define these unscaled universal ideas. We investigate a micrograph and the conditions it holds, extract principles from it, taking it outside of its scale specificity, and deploy it in a different scale with an intelligence that responds to requirements imposed by that secondary scale. Each project has a set of requirements dictated by how the architecture's intended use, or its program. These requirements give us the conditions to respond to once the universal principle is enacted in a specifically scaled architecture project.

Students observe, analyze and draw, deriving systems of measure. They translate their observations into a universal abstraction. Extracting structural, spatial and tectonic principles embedded in the micro scale from which to develop a language of building. They identify core ideas identified in language "word joint" and understood in construction as a physical joint – abstract building blocks.

Act Three – Intervention

Based on site, scalar, and programmatic constraints, the design principles transform from the universal to the specific. In this instance each developed project manifests the qualities that are required for human centric design – be it the scale of a housing project re-addressing the urban/landscape scale, the scale of a pavilion, or a house.

Through the study of the micrograph, students identify universal principles that present opportunities for further developments in the context of an architectural project. We do not blindly adopt form, but open our minds to strategies that could be translated from one scale to the other, studying the programmatic implications of this act of translation.

Results - Case Studies

A semester's work is not merely the final project delivered at the conclusion of a semester, but it is the process itself. I explored this approach in my paper "out of time" (Erel, 2012) where I explain that in the design process we make a series of artifacts that are connected, but once they are built, they become autonomous. This duality presents a design process where artifacts can be reintroduced with a different reading in a nonlinear fashion, presenting the student process as a temporal merge of 'being' (moments in the process) and 'becoming' (the process itself). Therefore, I will reference different artifacts or moments–drawings, models, and renders–of each student's process to be able to explore the process of each of the three acts.

From a broad range of projects taught over a ten year span, I have selected a number of projects from different studios ranging from a foundational first-semester, first-year studio designing a pavilion or kindergarten building, to a second-semester. first-year studio studying a pavilion, to a housing project in a fourth-semester, second-year project, where students are asked to respond to a larger set of constraints. Each one of the examples allows us to see either a different aspect of the process, or how scale and program may impact the outcome of an investigation.

The foundational kindergarten- Case Study

I will start with a case study that examines work in a first semester architectural design studio. To begin, I have selected a kindergarten program, as it relates to scale quite directly. The programmatic constraints of a kindergarten are scalar in nature since they involve adults as well as children, leading to a variety of sizes and scales to consider. As a pedagogical approach, the kindergarten uses playfulness as an educational tool (Montessori, Zinger), hence students are encouraged to embody a playful attitude in the design of the architectural environment. We draw on Dewey's observation that "What nutrition and reproduction are to physiological life, education is to social life" (Dewey**,** 1916) and use it as a design guide. This studio took place in the students first semester studying architecture, where they developed both their skills and an introduction to the world of construction tectonics and material.

In both kindergarten development projects, the students first unpacked a micrograph image through a series of drawings studying the structure of the image (See figure 1A and 2A). The students defined the universal condition in the image in two words, a verb and a noun and developed study models that reflected on those conditions in a tectonic way (for example in Kindergarten Project 1 they coined the terms Cluster Assembly and Intersecting Network - figure 1A and in Kindergarten Project 2, they defined the condition as Contracting Cell - figure 2A). From the universal principles students develop grids and models that would be the beginning of their tectonic language (see figures 1B, 2B).

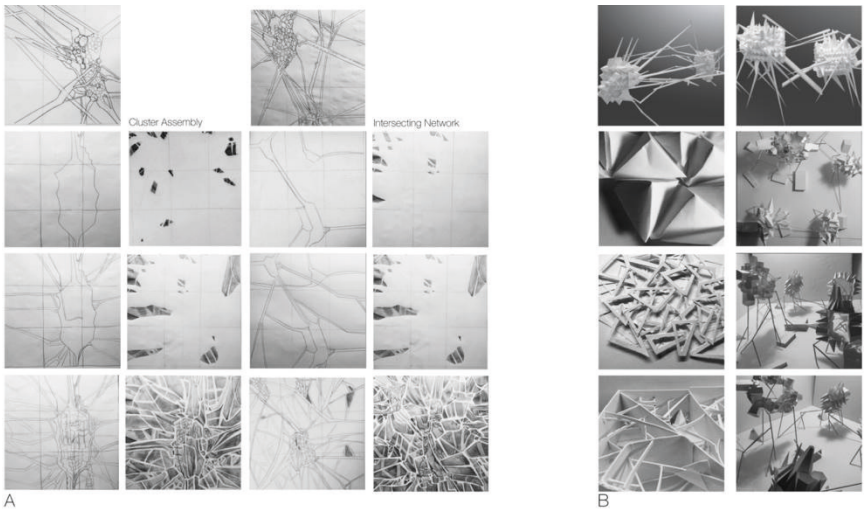


Figure 1 - Kindergarten Project ex.1 in Architectural Design Studio 1 - Extracting a Universal design language
A) studies of rain coat fibers, based on Micrograph - Pencil on paper by student B)Study *Models.*
Student work by Abigail Light, RPI Fall 2020.

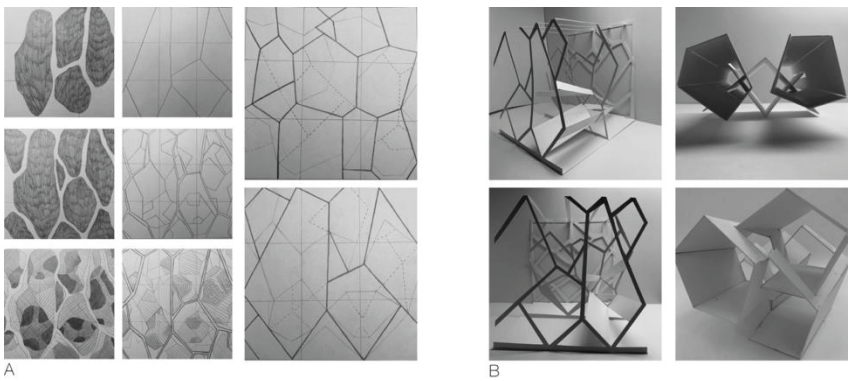


Figure 2 - Kindergarten Project ex.2 in Architectural Design Studio 1 - Extracting a Universal design language
A) studies of rain coat fibers, based on Micrograph - Pencil on paper by student B)Study.
Student work by Hellen Worden, RPI Fall 2020.

Once the students engage with the kindergarten program requirements, they enact the tectonic principles they developed from the micrograph analysis and address program requirements.

In Project 1, the structural fibers in a raincoat (Figure 1) are translated into linear structural members as well as programmed circulation elements such as slides and walkways (Figure 3), whereas the massing elements developed in stage one become whimsical classrooms envisioned as adventure play pods with unique light and program qualities (Figure 3).

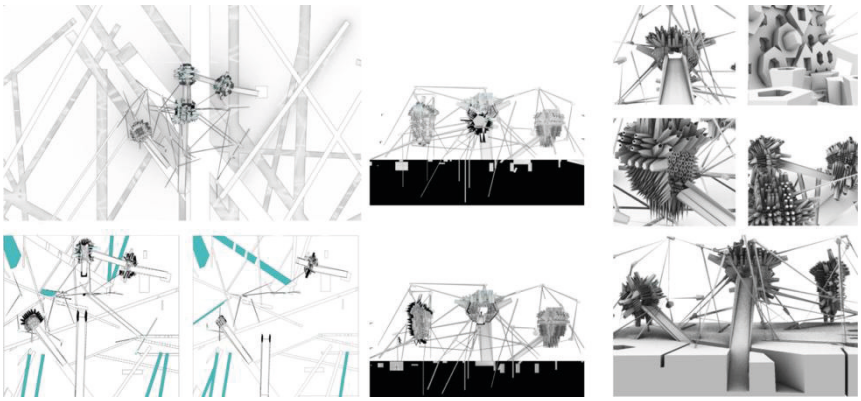


Figure 3 - Kindergarten Project ex.1 in Architectural Design Studio 1 - plans sections and model
Student work by Abigail Light, RPI Fall 2020.

In the second kindergarten example, we see how the student built on the distinct language developed based on individual caribou hair cell structures (Figure 2) in multiple scales; for example, the student created large spatial divisions as well as smaller scale elements of play and occupation (Figure 4). The process of universal translation allows the discovery of tectonic possibilities that could manifest in a variety of ways depending on the requirements that are placed on the architecture.

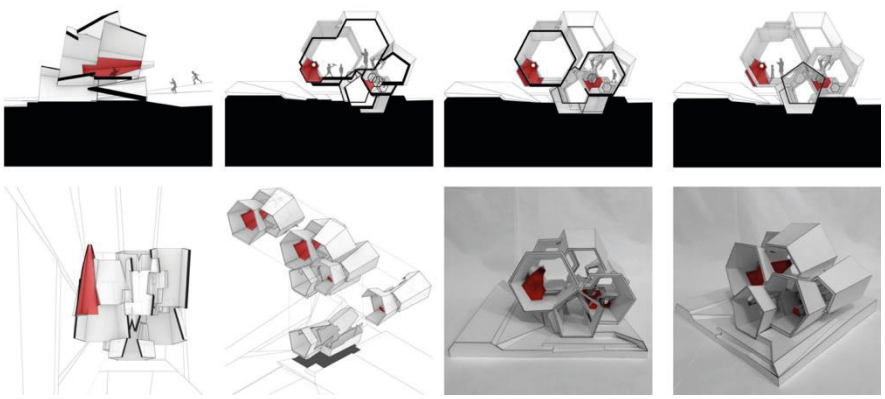


Figure 4 - Kindergarten Project ex.2 in Architectural Design Studio 1 - plans sections and model.
Student work by Hellen Worden, RPI Fall 2020.

The Urban Pavilion – Case Study

The urban pavilion is also an example of a first semester studio project. In this semester, students photographed their own micrograph with a hand-held, close-up microscopic camera (see Figure 5). This technique allowed the students to uniquely understand the object they were investigating, taking into account the multiple aspects that affect our spatial understanding of the element as a whole. This way, students understood what we can see with our naked eye in contrast to the depth we could see with an enhanced 'mechanical eye' (i.e. the microscopic camera).

Developing their project, students explored key aspects in the microstructure of sea creatures. Based on architectural consideration of occupation, light, view and sequence, students chose how to deploy different characteristics adapted from the microscopic scale. From porosity to structure, the characteristics evolved to capture architectural requirements and desires.

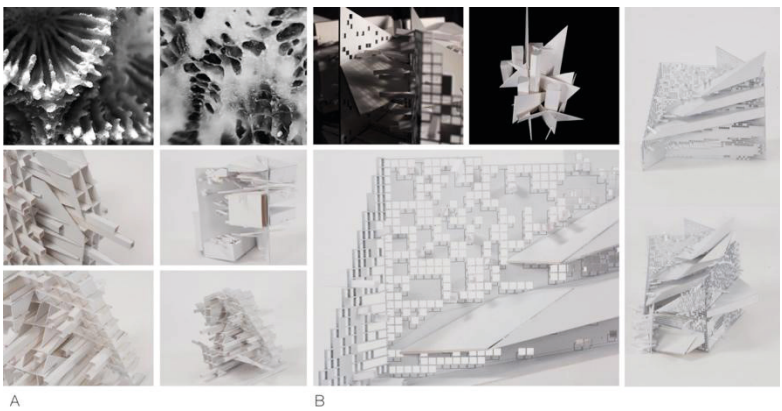


Figure 5 – Pavilion Project in Architectural Design Studio 2 - A)Microphotograph of a coral and initial development of tectonic language B)Initial tectonic Models.

Student work by Olivia Krewer, RPI Fall 2015.

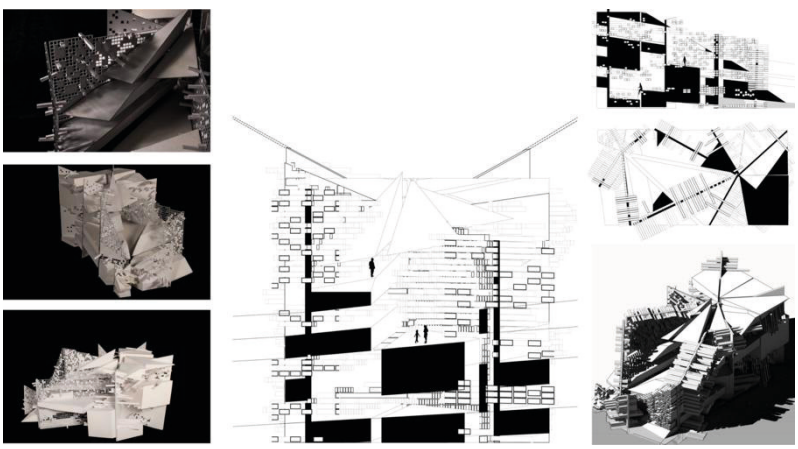


Figure 6 – Pavilion Project in Architectural Design Studio 2 - Plan Section and and model of Pavilion.

Student work by Olivia Krewer, RPI Fall 2015.

The Observation Machine – Case Study

The *Observation Machine* is a Pavilion on the water edge. Students looked at the act of observation as pivotal to the development of the architectural requirements of the pavilion. The *Observation Machine* asked students to observe conditions through the architecture that may not be visible otherwise: light, sound, water flow, water levels, etc. Similarly to the urban pavilion and kindergarten project, students took a close look at the microscale and mined it for structural, tectonic and organizational insight (See analysis of the structure of a coffee bean in figure 7).

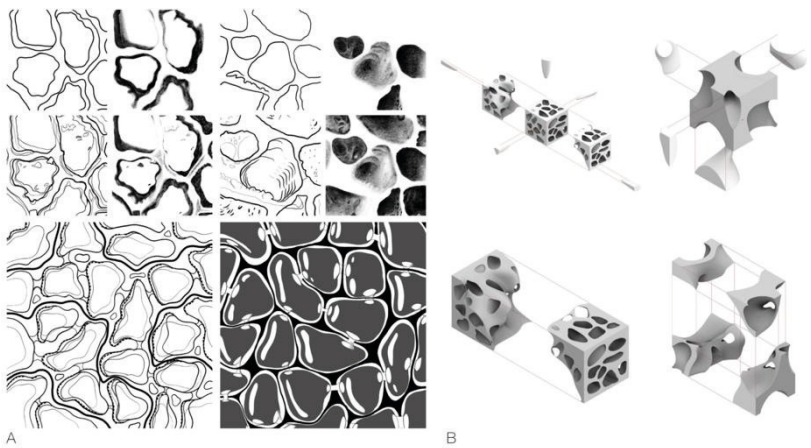


Figure 7 – Observation Pavilion Project in Architectural Design Studio 2 - A) Analysis of Coffee Bean structure B)Development of tectonic models.

Student work by Javier Torres, RPI Spring 2022.

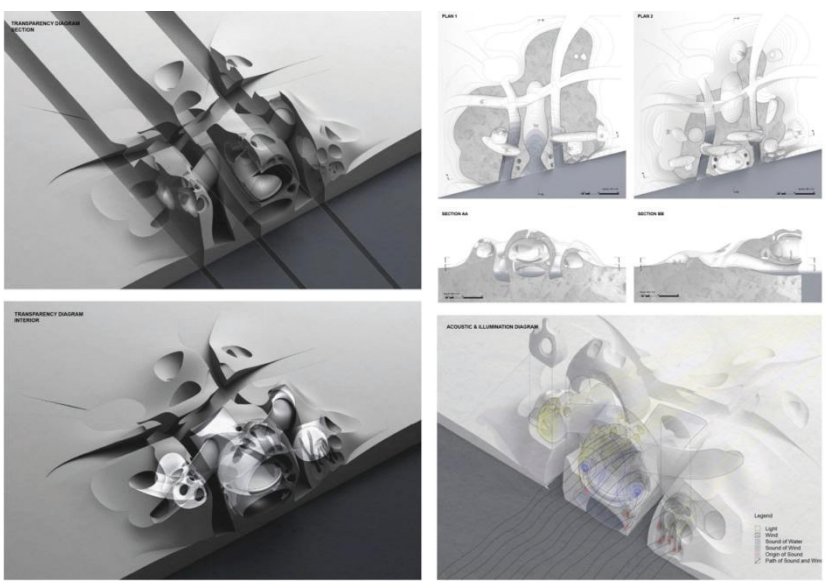
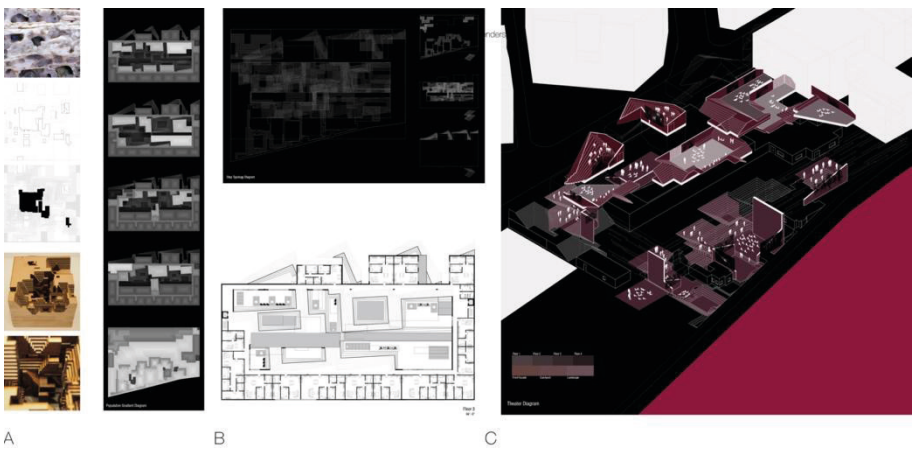


Figure 8 - Observation Pavilion Project in Architectural Design Studio 2 - Plans, sections and diagrams of pavilion.

Student work by Javier Torres, RPI Spring 2022.

Urban Housing – Case Study

Lastly I would like to look at an example that architecturally relates to the urban and dwelling unit scales–an urban, high-density housing program. In these scales the implications of the micrograph are played out relative to a more complex program and addresses a larger urban fabric. In both examples below (Figures 9-12), students located artifacts on the proposed project site and photographed them to reveal micro--patterns and structures. Through analysis and investigation they revealed a structure that could be transposed onto a scaled architectural project. In Figures 9-10, we see the analysis of a rock–a seemingly solid stone–leading to a housing/film center that provides a porous urban community, a sponge-like housing project that allows the housing program to flow into the city and vice versa.



Figures 9 - Housing Project 1 in Architectural Design Studio 4 - A) Microscopic Studies – based on student micrograph of rock found on project site B) Plans C) diagrams.
Student work by Jessica Gentile and Sarah Morsches, Spring 2016.

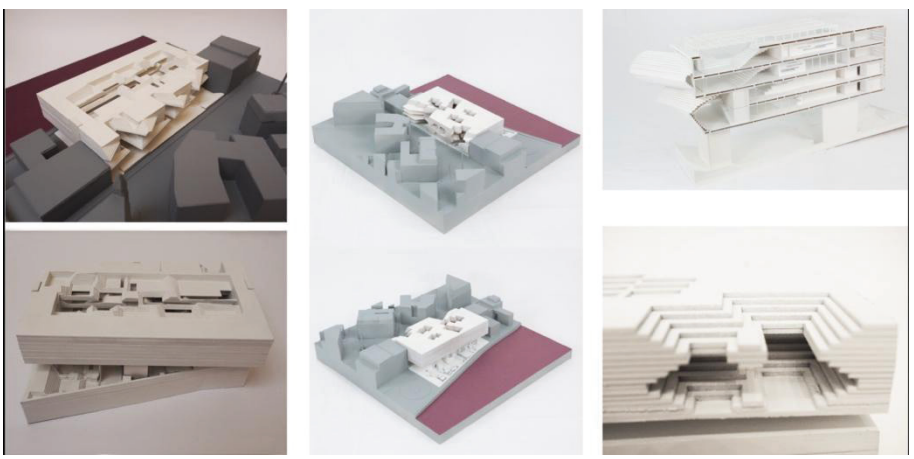
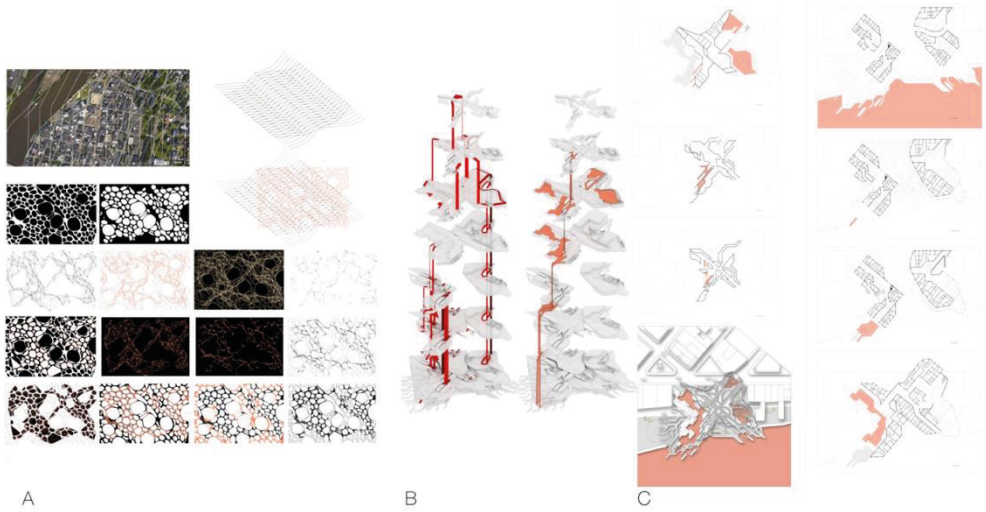


Figure 10 - Housing Project 1 in Architectural Design Studio 4 – Models.
Student work by Jessica Gentile and Sarah Morsches, RPI Spring 2016.



Figures 11- Housing Project 2 in Architectural Design Studio 4 - A) Microscopic Studies of leaf found on site and urban grid B) Housing Circulation Plans C) Housing Plans.
Student work by Xu Lui and Mengzhe Zhang, RPI Spring 2016.

Figures 12 - Housing Project 2 in Architectural Design Studio 4 - Models.
Student work by Xu Lui and Mengzhe Zhang, RPI Spring 2016.

In Figures 11-12 we see how the students merged the porous and structure of a found leaf with the underlying grid of the city. In the analysis phase, the students merged an urban grid with the leaf grid to find an organizing principle for their housing. They incorporated the flow of circulation of people and water as key ingredients in their project. In all presented cases, the students did not blindly copy a microstructure

and formally force the geometry to work in an architectural scale. Rather, they underwent a process of translation where they uncovered critical universal principles and asked larger questions of them–questions that could be answered in a specific scale of inquiry.

Conclusion

Micro-structures hold teaching potential. The microscale is constructed by a distinct, non-human design process. It opens the young architect's imagination to a different reading of what construction in the human scale may become. As we transform the observational scale, a new context emerges, which, if seen abstractly, can become a productive design tool that operates on different levels, from actual biomimicry–learning from biological structures–to a foundational tectonic lesson–observing formal and organizational principles to inform a language of construction. In either strategy we use the micro scale's abstract principles and formal strategies that translate to the question we are posing in that design stage/scale.

In different scales of design, the impact of the micro structures on the process may be different. When looking at early initiation to architecture (i.e. first and second semesters), this point of departure serves as a way to challenge assumptions about architecture. Students begin to see architecture as a language, and find new ways to conceive of formal strategies, material composition and production. At this stage, we use the micro-structures as a way to link concept and form, as well as create a design strategy in multiple scales of inhibition, taking special care to look at ergonomic criteria that may affect the design at the human scale.

Once we get into slightly more advanced years (shown as a fourth semester housing project in this paper), students have a better grasp on architectural tools and concepts. A housing project, which in itself is multi scalar, operates on urban, housing aggregation, unit and detail scales. In this stage of their education, students can use the micro-structures as a way of questioning new structural ideas and urban approaches, as well as a way to elevate standardized design with another set of logics. At the urban scale, we can see examples of extending the micro-scale logic into questions of edge, flow of view and site, as well as create different types of urban voids and continuities. The microscale can be read and re-read to provide different insights at each scale, all the while also providing a new way of seeing the physical world. Entering from a micro-scale unleashes potential readings that allow for a fresh tectonic interpretation that is both anchored and abstracted and could be highly productive in fostering creative yet tectonic imagination.

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