Nature of Structure
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Introduction

Architecture students, curious and inspired, are challenged to insert and assert themselves in the discipline. They engage in research by exploring the world around them, striving to understand and find relevance and interconnectedness. They aim to discover the value and meaning of precedent whether natural or manmade, and to develop effective design processes. As the future stewards of the constructed environment, it is paramount that they are expansive and free in their imagination, but responsible and ethical regarding the aesthetic, technical and intellectual consequences of their actions. This article presents the Nature of Structure exercise, which defines and employs a methodology that encompasses research, precedent and design development processes. It challenges architecture students to examine nature as a precedent for functional design.

Functional Design

Michael French, in the opening of his book "Invention and Evolution," invites the reader to consider a buttercup, a waterfall and a steam locomotive. One is asked to consider which is the odd one out. He posits that one might consider the buttercup because it alone is alive, or the locomotive because it alone is manmade. He gravitates to the waterfall because it alone lacks the dimension of design. He utilizes this example to illustrate that functional design in nature and functional design as a process of human imagination are rooted in the same principles. The Nature of Structure exercise considers structure the subject of functional design because architecture students are predisposed to kinesthetic learning and structure is conducive to clear performance criteria, can be easily demonstrated and empirically evaluated through physical modeling.

Nature as a Realm and a Disposition

The Nature of Structure exercise considers two dimensions of the term nature. The first, nature as a realm, is defined as the “phenomena of the physical world collectively... features and products of the earth itself, as opposed to humans and human creations.” The second, nature as disposition, is being the “innate or characteristic disposition” of a thing.

As a realm, nature can be perceived as a pure unadultered system, comprised of living organisms negotiating physical conditions in compliance with the fundamental laws of the universe. As contemporary western society evolves it grows increasingly distant and distinct from this romantic existence of nature, moving toward what Peter McCleary refers to as super-supernature. This distance enhances the objectivity with which society regards nature. It is an abstraction, a foreign realm, a curiosity and a source of inspiration. In the disciplines of architecture and engineering, nature presents difficulties to navigate, opportunities to exploit, and potentially a paradigm for solving the problems endemic to the realm of super-supernature.

Nature as disposition recognizes the specific character of a given entity. In the natural realm this disposition is exemplified in plants and animals being endemic to specific natural conditions, and a product of evolution in
response to those generative conditions. In the manmade realm, nature as disposition can be illustrated through Louis Kahn’s Socratic dialogue with the brick; revealing not only the basic nature of the brick as a modular compressive unit but its potential to maximize its nature by defying gravity as an arch. Herein lies the capacity of humankind as Homo Faber to exploit the resources and maximize the potential of natural specimens as created by Deus Faber. Maximizing natural potential is not a claim that Homo Faber can do better than Deus Faber, but acknowledging that the capabilities and conditions endemic to the manmade world are different from those of the natural world; warranting a mechanism for translation. Robert Le Ricolais stated, built form “must obey but not mimic nature.”

**Methodology**

The Nature of Structure exercise defines and employs a research methodology where design potentials are harvested and derived from natural precedents. The exercise does not employ a practice methodology, where the design is a solution to a problem defined by site and a functional program. This is a critical distinction for architecture students who often first look outward for solutions before effectively defining problems, which leads to the development of solutions that are in turn searching for problems; a decidedly absurd process for the professional practice of architecture. The research design methodology employed in this exercise has implications for a professional design process in the form of logical mechanisms used to critique and construct identities for designed entities.

**Analogy and Similar Differences and Different Similarities**

The Nature of Structure exercise explores and defines the relationship between natural precedent (the realm of Deus Faber) and the manmade (the realm of Homo Faber) through the use of analogy and David Bohm’s concept of similar differences and different similarities. “Analogies illustrate things which are very difficult to comprehend.” If employed critically, analogy can be a powerful instrument. Enabling one to initially identify the commonalities between two things and subsequently clarifying the differences; leading to a respectful understanding of two autonomous identities. In a design process it is paramount that the differences be identified and distinguished, or the risk of the analogy becoming a literal metaphor (this is that) will prevail. If approached superficially, analogy as a literal metaphor leads to a bridge inspired by a snake becoming a bridge that assumes the image of a snake rather than a self-respecting bridge that employs performative systems derived from a snake. David Bohm states, “judgments of order are based on the perceptual discrimination of similar differences and different similarities.” In the analogous relationship between a natural specimen and a manmade entity one can define categorical constants as similarities, and conditional / performative variables as differences. Categorical constants might include geometry, material and force management. Conditional / performative variables might include the specific properties and means (nature) of the geometry, material and force management systems in their respective contexts. If one considers the categorical similarity of force management in a natural specimen and a manmade entity, one is likely to identify the difference in performance. A natural specimen might manage forces through dissipation where a manmade entity might manage forces through resistance. This acknowledgement prompts inquiry into how the geometry and / or material of the respective entities facilitate the performance of their respective force management strategies. Concomitantly, material in a natural specimen might be grown where as material in a manmade entity might be extracted, processed, dimensioned and assembled. There may be a
geometric similarity between the entities but the inherent differences in the respective material natures warrant dialectic examination. This use of similar differences and different similarities to examine the relationship between two analogous entities is employed to construct identity, as a manmade design is derived from a natural precedent.

**Project Proper**

The Nature of Structure exercise is delivered as an elective course in the architectural curriculum at the University of Arizona. The exercise is comprised of four stages: Precedent, Abstraction, Application and Alteration.

**Precedent**

Students are asked to select a compelling natural specimen that will serve as the precedent and catalyst for all subsequent stages. The specimen is to be a plant or animal that is physically accessible. Students typically forage our local Sonoran Desert where unique plant and animal specimens are abundant and available for observation in their natural contexts. In the case of animals, students venture out into other university departments that work with insects and animals, seeking takeaway specimens. It is imperative that the specimens be physically accessible in order to facilitate direct physical examination, providing a personal empirical experience that draws upon the full breadth of the students’ senses and intuitions. If the specimens are not directly accessible the students must overcome the bondage of opacity and indirectness imposed by working through the conclusions of third party researchers.

Once identified and acquired, each student is challenged to understand the nature of their respective natural specimen as a product of its generative conditions, defining its physiological essence in terms of functional systems, geometry and materiality. Students utilize observation, pictorial drawing, playful interaction, dissection and analytical diagramming to construct this understanding.

The four-stage process is exemplified through a student’s project that begins with the Palo Verde tree as precedent [Fig. 1].

![Fig. 1: Precedent: Palo Verde Tree and Branch (R. Meeks)](image)

The Palo Verde tree is endemic to the Sonoran Desert. Prima facie, the identity of this drought deciduous tree is defined by its shrub like form, erratic thorny branches, green skin, and annual yellow blossoms. Through empirical exploration the student was drawn to the physiology of the individual branches; observing that when exposed to wind the branches resolve the forces through dissipation. The branches were understood to be cylindrical, tapered, and comprised of segments bound by articulated nodes; configured as a helical spiral completing a full cycle every five nodes. The nodes appeared as rigid concentrations of material where growth of new branches or thorns occurred. Through this abundance of material they also provided strength through resistance, leaving the linear segments bound by the nodes to dissipate forces through axial torsion, facilitated by their relative weakness and the form bias of the helical branch geometry.
Abstraction

This stage requires students to abstract one or more dimensions from the natural specimen. The dimensions are to be explicitly physical and inherently structural. For the purposes of this exercise, abstraction is considered to be reductionistic, the isolation of properties, as opposed to the common misinterpretation of abstraction as generalization or an abstruse perception. This process of abstraction requires students to extract the structural/physical dimension from the context and conditions of the natural specimen. This process requires clarifying that which is extracted (constants to become different similarities) and that which is left behind (variables to become similar differences). Some students experience difficulty with the intellectual interpretation and decisiveness required by this process. In the context of the Palo Verde tree branch, one may be inclined to make a manmade branch rather than to render a helical spiral with a faceted linear element comprised of rigid joints and flexible segments.

The Abstraction stage is exemplified in Figure 2. The student developed a series of models and drawings as a means to achieve a clear and finite abstraction. The final products of that process are depicted. Translation is inherent to the process of abstraction. Both the branch and the abstraction are defined by linear elements that are flexible where they are straight and rigid where they change orientation. The cores of both the branch and the abstraction are compressive; in the branch the core is rendered in older stiffer heartwood, in the abstraction it is rendered in reinforced PVC tubing, filled with anchoring cement and terminated with wood dowels. Tension is concentrated in the perimeters of both the branch and the abstraction; the branch accommodates this stress through supple sapwood while the abstraction renders the tensile zone in a diagrid weave of monofilament nylon line. Upon the completion of this stage the abstraction ceases to be a branch.

Application

Abstraction leads to expansion through application. The application stage requires students to adapt and develop the abstraction in a new context comprised of different conditions and performance criteria. Although different they are perhaps similar to those of the natural precedent. The Application stage of the Palo Verde project is depicted in Figures 3 and 4.

Fig. 2: Abstraction of Palo Verde Branch [R. Meeks]

Fig. 3: Application: Columnar Structure, Aircraft Plywood and string [R. Meeks]
The student applied the abstraction to a self-supporting vertical columnar structure that resists incidental loads through dissipation, similar in performance to its analogue the Palo Verde branch. The context of the application is a static base differing from that of the branch, which was yet another branch within a bifurcated hierarchical network. The composition of the model in figure 3 is developed, rendering the compressive spine as a series of interlocking planar ribs bound by a unidirectional tensile weave that transfers force through compressive diaphragms regularly distributed along the compressive spine. The performance of this model lacked the intended clarity of deformation. The nodes provided adequate resistance but the deformation of the segments was concentrated about the discontinuous material located in the middle of the segments. The student utilized this model as scaffolding for the subsequent model [Fig. 4].

This iteration dissolves the language of differentiated systems of tension and compression; combining them into a flexegrity system. This model is comprised of a bi-directional weave of piano wire, soldered at the intersections. The circular cross-section increases at the nodes, offering more rigidity by distributing the material more efficiently about the perimeter. Conversely the material is distributed less efficiently at the middle of the segments, facilitating localized torsional deformation. The geometric and material composition of this iteration was also more inherently adaptable to the static base.

Alteration

“To make a difference anywhere is to make a difference elsewhere.” The alteration stage requires students to introduce change. The alteration of a single condition or performance criterion instigates a re-calibration of the interrelationship of all performance criteria. Alteration thereby furthers the potential versatility and adaptability of the abstract structural dimension.

In the alteration stage of the Palo Verde project, the student changed the form from columnar to planar [Fig. 5].

This first alteration model retains the system of nodes where resistance is maximized and the areas in between the nodes where forces are dissipated. The cross-section geometry of the plane retains the strategy of the previous stage, distributing the material most efficiently where rigidity is desired and less efficiently where deformation and force dissipation is encouraged. The second alteration model [Fig. 6] embodies further development, replacing the integral base with a serpentine geometry at the base of the model, rendering it self-supporting.
Conclusions

Following the completion of the Nature of Structure exercise the student that undertook the Palo Verde precedent continued development, further adapting the system through application to their senior project titled “Adaptable Enclosure for Arid Lands.” The system derived from the Palo Verde branch became the logical and structural basis for a multi-dimensional environmentally responsive enclosure system integrated into the architectural design of a school.

Students typically decide to take the Nature of Structure elective course because they are curious about nature and bio-mimicry, and have an interest in exploring structural form. Upon completing the four-stage exercise they commonly express, most emphatically, an appreciation and respect for the methodology. A student who took the course in 2001 remarked, the Nature of Structure exercise “radically changed the way I think about architecture, afterwards my studio projects took on a different character, I asked simpler questions, with more focus and let those questions drive my work.”

Most recently a student who took the course in 2012 remarked, it was “transformative in clarifying and establishing a model for investigation; the most surgical exploration of how I think, I notice now that when I design I gravitate towards this process.” This feedback usually comes as they embark upon their next design studio course; as they believe they are empowered with a new ability to navigate a conventional architectural design challenge.

Notes


3 Ibid.


7 Ibid., 9


10 Madeline Gradillas, BArch 2003

11 Levi Van Buggenum, BArch candidate 2013