

Seeding sequence: a process for developing complex adaptive systems

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ABSTRACT: Engaging architecture as an emergent, complex system, this paper examines the implementation of a critical design approach -- the Seeding Sequence -- in two diametrically different studio courses: A 5th year Integrative Design and a 1st year Beginning Design one. Drawing from a Systems Thinking approach to understanding relationships, this critical design approach trades the designer's impulse for formal control and fixation of the architectural object for one of a complex adaptive system. Framed against three past pedagogical approaches to beginning design, the Seeding Sequence process guides the students to work in a recursive cycle between two competing modes and scales of investigation: a modeling method that revels in the detail and a drawing method which considers the context. The Seeding Sequence moves beyond procedural actions by requiring a level of abstraction between the two methods. This paper presents the process, final results, and selective answers from the students' evaluation from both studios this paper concludes by discusses the effects of this design process on three aspects of the students' work: 1) withholding the ability to preconceive the result. 2) framing one methods of investigation against the strengths of another. 3) establishing direct connections between the design decisions and the unique attributes of the materials, program, and site of the project. This paper concludes by critiquing that the specific methods of investigation are selected to challenge the skill level of the students and the resolution of architectural design thinking required by the course. But more importantly, the pairing of two methods -- specifically two with dramatically different benefits and outcomes -- establishes an awareness in the student to actively question what each new method brings to their design process.

KEYWORDS: Design Pedagogy, Beginning Design, Integrative Studio

1.0. PRINCIPLE ACTION

Being creative is not just a matter of casting about for something novel—anybody can do that, since novelty can be found in any random juxtaposition of stuff—but of making the novelty jump out of some system, a system that has become somewhat established, for good reasons.

--Daniel Dennett, *Intuition Pumps and other tools for Thinking*

As in all adaptive systems, maintaining a correct balance between these two modes [unfocused and focused] of exploring is essential. Indeed, the optimal balance shifts over time. Early explorations, based on little or no information, are largely random and unfocused. As information is obtained and acted on, exploration gradually becomes more deterministic and focused in response to what has been perceived by the system. In short, the system both explores to obtain information and exploits that information to successfully adapt. This balancing act between unfocused exploration and focused exploitation has been hypothesized to be a general property of adaptive and intelligent systems.

--Melanie Mitchell, *Complexity: A Guided Tour*

With a cursory comparison of the NAAB criteria assigned, student-to-teacher ratios, and project briefs it can be said Beginning Design and Integrative Design are quite possibly the most disparate studio courses in our B.Arch curriculum. In addition, as Integrative Design is the 10th and final studio of our sequence, these two courses exemplify an extreme difference in the accumulated experience of students entering their respective class. The Seeding Sequence is an attempt to identify a process of investigation that remains critical regardless of the studio level or student skillset. Drawing from a Systems Thinking approach to understanding relationships, this critical design approach trades the designer's impulse for formal control and fixation of the architectural object for one of a complex adaptive system.

Implemented in beginning design to circumvent nascent students' preconceptions of creativity and novelty in design, this critical design approach returns to confront habits adopted through four years of academia in the fifth-year Integrative Studio.

Framed against past pedagogical approaches to beginning design, this paper defines a series of key concepts of Systems Thinking with specific focus on Complex Systems as defined by Melonie Mitchell's work on Artificial Intelligence, to outline a design process. The Seeding Sequence process is first presented as an abstract framework, removed from either studio. The individual year levels are then presented with specific focus on the methods of investigation and exercises that are employed by the students.

Through selective examples from both studios, this paper concludes by discusses the effects of this design process on the students' ability to self-critique by: 1) withholding the ability to preconceive the result. 2) framing one methods of investigation against the strengths of another. 3) establishing direct connections between the design decisions and the unique attributes of the materials, program, and site of the project.

2.0. FOUNDATIONS

2.1. Beginning design pedagogy

For context, this paper is being written while I sit on an Ad-Hoc curriculum committee discussing a possible return to a Common Foundations studio across our entire College -- the Architecture, Landscape Architecture, Interior Design, and 12 tracks of the Art school. Discussions on this committee have led me to reflect on the aspects of my beginning design education that have been fundamental to the success I have found instructing beginning design and upper level comprehensive studio over the past 10 years. I believe it is this ability to separate the lessons learned from the contrivancesⁱ assigned, that plays a significant role in an instructor's ability to reach ever younger generations of students.

Through my first beginning design assignments -- Point, Line, and Plane -- I can trace the reductive formal studies of Bauhaus' Wassily Kandinsky and Paul Klee through an American take on abstraction defined by Arthur Wesley Dow and Denman Waldo Ross' *Pure Design* at the Graduate School of Designⁱⁱ. Paul Klee's Sketchbook, handed to us by the faculty, acted as a Rosetta Stone to the world of 2D compositional languages. With little direction given, the four-exercise sequence allowed the students (myself) to revelⁱⁱⁱ in Paul Klee's concepts of composition; Proportion and Structure, Dimension and Balance, Gravitational curve, and Kinetic and Chromatic Energy^{iv}.

Paul Klee replaced deduction by Induction. Through observation of the smallest manifestation of form and interrelation ship, he could conclude about the magnitude of natural order. Sibyl Moholy-Nagy

For both Froebel And Itten, students learned by doing, experimentation for its own sake was encouraged

and "play" was considered key in imparting important theoretical discoveries. Fern Lerner

Later projects in my beginning design education drew directly from Steven Holl's reinvention of Columbia Universities Master of Architecture First-Year in 1986 under Kenneth Frampton. Although we did not design a cabin for a Poet/Riveter, our project briefs made direct reference to the kit-of-parts and abstract site conditions of Holl's Point-Line and Line-Plane projects^v. In this series the students explore the objectives, site, and materials to develop an independent approach to designing meaningful experience. In comparison to free play building off Klee's manifesto, these projects represented a complete pedagogical reversal -- project briefs that withheld a state lesson.

In each of these assignments, an introduction, and develop of, self-critique played a significant role. An internal question as simple as "Is this point so large it is now a plane?" introduces the self-critique and authorship in design. Whereas, with Steven Holl's projects at Columbia, self-critique as an internal voice is nurtured as each student is tasked to discover ideas within themselves that elevate the initial prompt. In both examples the process of designing is left to

the students. As integrative design criteria highlighted in NAAB *C2 Integrated Evaluations & Decision-Making*^{vi} exemplify today focus on transparency and quantifiable accountability, how can a beginning design course develop the self-critique inherent in past pedagogy while facilitating today's professional agendas?

2.2. Systems thinking

Scientist, instructor, and author, Donella Meadows earned the MacArthur Foundation 'genius' award in 1994 for her contribution to the understanding of dynamic complex systems. Her international bestseller, *The Limits to Growth*, along with the follow up *The Global Citizen* and *Beyond the limits* introduced a Systems Thinking approach to understanding the relationships between social and economic systems and today's environmental concerns. Meadows discusses Systems Thinking as a problem-solving technique in her final book, *Systems Thinking: a Primer*. Here she defines a system simply as an interconnected set of elements coherently organized in a way that achieves a result^{vii}. She goes on to explain that all systems have three key elements: components, interconnections, and a function or purpose. This approach to understanding relationships is scale-less, with examples in the book ranging from balancing-systems, such as, the cooling of a cup of coffee in a cold room, to reinforcing-systems like "success to the successful" playing out at national economic scales. In either case, using a Systems Thinking approach to understand the Elements at play, the Interconnections between those elements, and the Purpose that come from these interactions, creates a framework for an inclusive, multidisciplinary approach to problem solving.

2.3. Complex systems

Melanie Mitchell, a Professor of Computer Science at Portland State University, received her PhD from University of Michigan in computer science, where, in collaboration with her advisor Douglas Hofstadter, her dissertation focused on the development of artificial intelligence through a computational understanding of analogies. Her most recent book, *Complexity: A Guided Tour*, chronicles the history of complex systems leading to her exploration of cognitive science and complex systems as a means of approaching artificial intelligence. She begins by defining *complex systems* as networks that exhibit three identifying characteristics. First, they have a bottom-up logic -- there is not a central leader, but rather, complex systems are made up of individual components that have simple, established rules. Second, these individual components communicate with other internal systems (their neighbors) and external systems (their context). Thirdly, the individual components have the ability to adapt to the information they have received^{viii}. Mitchell further describes emergent behavior within complex systems as unique organizations developing at the macroscale from component-level interactions. These emergent responses are considered self-organizing and allow for heterogeneity and unpredictability^{ix}. Examples of these emergent responses range from the study of the complex interactions between ants in a colony to the synapse-exchanging neurons in our brain. Regardless of scale, political scientist Herbert Simons argues that the complexity of these systems can be measured by the depth of their hierarchy (the nesting of subsystems within a system) and the near-decomposability^x of the systems (the notion that individual elements in the systems have stronger logic within themselves than that which ties them to their neighbor).

2.4. Correlating systems thinking vocabulary

Adopting Donella Meadow's Systems Thinking logic as a framework for architectural inquiry, the Components are identified as the students developed assemblies, program requirements, and site characteristics. The Interconnections refer to the relationship, or organization, of these components. For use in these design studios, the Purpose is to design architecture that is responsive to its internal and external systems.

Drawing from Mitchell's definition of complex systems, the proposed design process -- Seeding Sequence -- prioritizes establishing a simple structural logic at the cell level. For this paper, and in both studios, a cell is identified as an Adaptive Assembly. This process demands the Adaptive Assemblies demonstrate a structural logic that responds to the composed

materials. In addition, the Assemblies' internal connections are investigated as nested subsystems to demonstrate near-decomposability.

2.5. The seeding sequence

In the sciences, models are discussed as simplified representation of “real” phenomenon. Appreciating that *all models are wrong, but some are useful*^{xi} we recognize the need to acknowledge the focus or benefit of one modeling method over another. Within architectural design, if we consider this idea of modeling the “real” as methods of drawings, diagrams, physical and computational models, we can appreciate each represent inquiries into the “real” with varied benefits. In both studios presented, the instructor specified the two methods for their ability to complement -- not necessary coordinate -- each other. By introducing these methods as a competition for leadership in the design process, students develop the ability to identify for themselves the benefit of each method.

Pitted against each other in a recursive cycle, a modeling method explores the impact of structural logic and material characteristics at the Adaptive Assembly level, while a drawing method facilitates the exploration of emergent behaviors at the macroscale. In each studio, the Adaptive Assemblies are developed first. Once the Adaptive assemblies have been constructed in one modeling method, a diagram of the Adaptive Assembly is seeded on a site in the competing method of investigation. (It is important to note an act of translation at this stage. The modeling method is not “rendered” in the drawing method, rather, the structural logic of the assembly is diagrammed. This moves the Seeding Sequence beyond a procedural process. With this abstract linkage, the designer’s ability to distill and diagram the essential logic, allows the Adaptive Assemblies’ compositional qualities to remain in the domain of the modeling method, while enabling the drawing to pursue emergent opportunities.) Emergent behaviors are discovered as the diagrams are allowed to rotate, repeat, and scale in response to internal system relationships (logic between assembly to assembly) and the external system opportunities of the program (circulation, spatial adjacencies, views...) and site (topographic, environmental, historic relevance...). In both studios, as the student adjusts the priority of various qualitative and quantitative elements of the project, the emergent behavior of the complex system responds accordingly. After multiple emergent scenarios are nurtured, the behaviors are assessed through inductive reasoning. This bottom-up approach allows for the discovery of an unpredicted intent or general concept. With the concept clear, a deductive process of design research refines the project efficacy. A recursive folding of this macroscale intent returns the designer to question the Adaptive Assemblies. How can the emergent order influence the evolution of the Adaptive Assembly? How in turn can the evolution of the Adaptive Assembly refine the macroscale results?

3.0. BEGINNING DESIGN STUDIO

3.1. Project outline

For the first semester beginning design project, students are asked to conceive a path that integrates five spaces into a given site. Through the semester, a single site is repeatedly challenged with increased programmatic and site requirements that demand a re-evaluation of prior design decisions. The iterative nature of the project sequence reinforces the benefits of a critical design process while allowing craftsmanship to develop.

The students begin by framing an architectural prompt into components, interconnections, and purpose. Within this process the purpose is to design an architectural intervention that is site-responsive to its landscape. Although subtle, the term “intervention” allows tectonic and stereotomic design decisions freedom from the student preconceptions of the word “building.” The components consist of the Adaptive Assemblies, the assigned architectural program, and site information. The program remains abstract with minimal area and adjacency requirements between a large “A”, medium “B,” and three small “C” spaces. As the project progresses, several spaces engage the topography as they must be embedded into the landscape. The final attempt includes the investigation of human scale circulation, sequence, and specified

views. The site opportunities begin with the consideration of the sun path and rough topography and as the project gains complexity, an entrance and exit to the site along with attracting and repelling points of interest must be responded to by the nascent designers.

Two distinct methods of investigation are employed in this beginning design project; the Adaptive Assemblies are developed through physical models made of found woods and metals while Emergent Behavior is explored at the macroscale through a multimedia drawing. The physical models begin with a series of material investigations to develop a catalog of connection types -- binding, pinning, and joining. These details are employed in the construction of Adaptive Assemblies. The Adaptive Assemblies must clearly communicate primary, secondary, and tertiary structural members while developing complexity within the connection details (subsystems).

At the beginning design level, Interconnections are discussed as the formal organization strategies of the assemblies. The students are challenged to communicate an understanding of the balance between order and novelty through a multimedia drawing. Formal order systems are disrupted as emergent behavior of elements respond to the site and program.

ADAPTIVE ASSEMBLY

Physical Model:

Material Characteristics
Structural Hierarchy



EMERGENT BEHAVIOR

Mixedmedia Drawing:

Site Circulation
Program Adjacencies

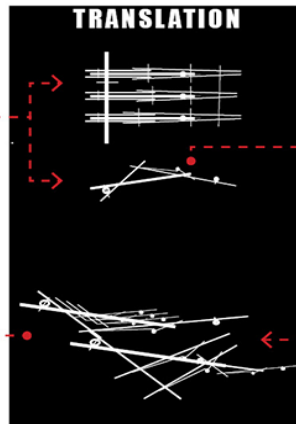


Figure 1. Process of Translation between competing methods of investigation, Beginning Design. Student C. Welch. (Author 2018)

The 2D method introduced this semester is a mixed media drawing consisting of a pastel base layered with 4H, 4B, and ink. The goal of this method is to develop the student's ability to fluidly move between the ambiguous (in this case pastel exploration drawings) to an analytical resolution (defined Euclidean elements) in ink. Each medium is paired with a purpose: *Gestures* in Pastels capture the site context. *Explorations* with light 4H graphite strokes explore emergent behavior in ordering strategies of the Adaptive Assemblies due to program and site opportunities. *Definitions* with 4B clearly articulate and annotate the emerging design elements. *Execution* in ink facilitates a level of resolution in design decisions that were previously unattainable. Although first stated as a sequential (linear) process, erasers are referenced as design tools which allow a continual fluctuation between the mediums -- a reworking of design decisions. Success is demonstrated through the ability of the process drawing to communicate an awareness of ordering principles -- grid, linear, radial -- while allowing complex emergent behavior to respond to the program and site. Once the students have become facile with the Process drawing, a class discussion frames that the use of multiple mediums had several agendas: one, establishing a range of 2D foundational skills; two, shifting a desire form a goal of achieving perfection for one of continual exploration and refinement. Once the students accept these ideas, the mediums selected are themselves irrelevant and more importantly is developing the ability to question how to think through the process of drawing.

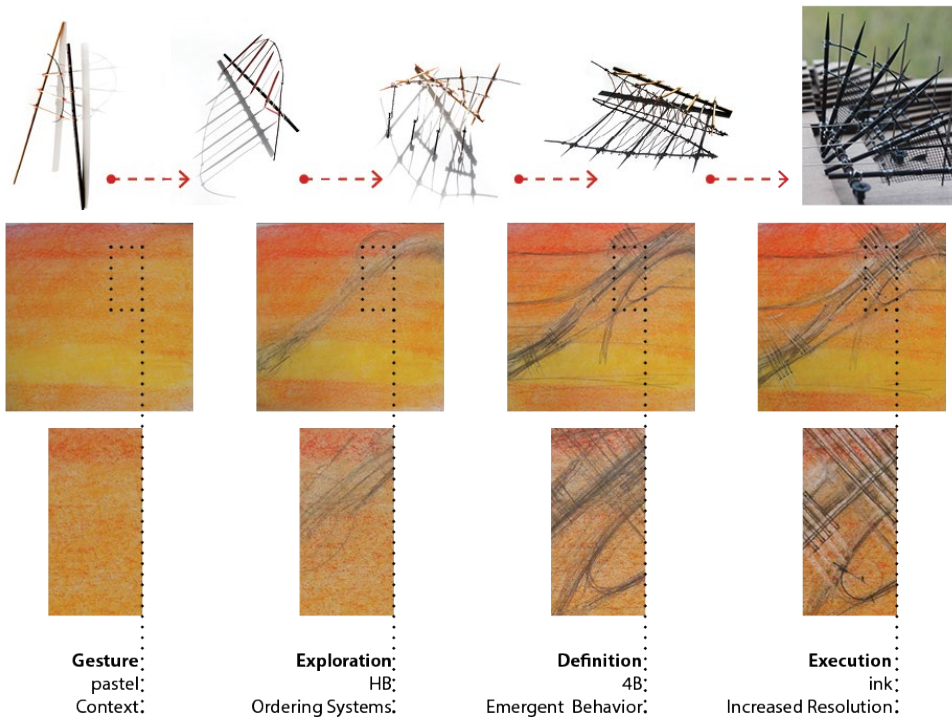


Figure 2. Adaptive Assembly Sequence by Ian Ledo. Process Drawing Sequence by Instructor. (Author 2018)

Student comments on the Seeding Sequence

“In the class, “drawing” quickly became more of a study tool and less of an art. Therefore, the ability to understand how blind exploration was used and could eventually provide certain ideas didn’t come easy in the beginning. It took overcoming that hurdle before I could understand how exploration meant seeing/finding new opportunities, and then how concentrating those opportunities meant seeing/finding an end product.” Beginning Design Student 01

“This design method has really helped me to loosen up with my design. Coming into the class, all of my pencil lines were hard and dark and every one of my designs are pretty set in stone after the first or second drawings. Through this method, I learned that if you are loose with your design, the possibilities are endless in what you can create.” Beginning Design Student 02

“I feel that I learned how to more efficiently experiment in designing, and how to explore more options and opportunities on the page in front of you. We learned to find some element of our work or create something special and fall in love with it and nurture it into something beautiful.” Beginning Design Student 03

“I found these processes very liberating in helping me to experiment without having a definite end result.” Beginning Design Student 04

4.0. INTEGRATIVE DESIGN STUDIO

4.1. Project outline

As the tenth studio in a Bachelor of Architecture program, this Integrative design studio is assigned a collection of NAAB’s synthesized criteria. A single project runs the entirety of the

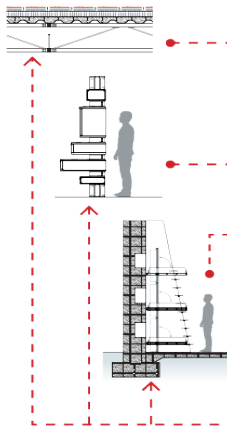
semester exploring a complex building program on a complex site^{xii}. The projects presented are proposals for a community radio station and adjoining 500-seat theater in a disaster-prone region. The projects will be measured on their ability to connect community engagement with the required functions of a relief shelter.

Utilizing the Systems Thinking framework, the students divide the prompt and their group research into components, interconnections, and purpose. In this studio, the components consist of the Adaptive Assemblies, the assigned architectural program, and site information. Within this process, the purpose is to develop an architectural design that is explicit in its response to the unique attributes of the materials, program, and site of the project. Two distinct methods are employed in this Integrative design project; a digital model is utilized at the Adaptive Assembly level while axonometric diagrams nurture emergent behavior at the macroscale.

ADAPTIVE ASSEMBLY

Section Drawings:

Material Characteristics
Structural Hierarchy



EMERGENT BEHAVIOR

Axonometric Drawing:

Spatial Adjacencies
Passive Design Strategies
Circulation

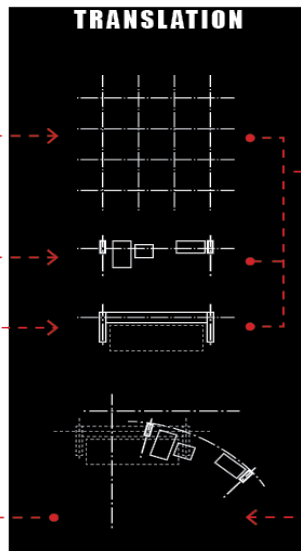
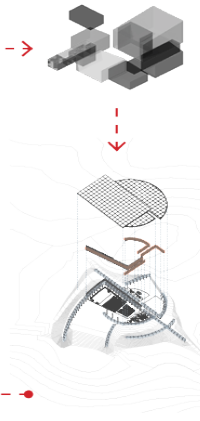


Figure 3. Process of Translation between competing methods of investigation, Integrative Studio. Student A. Verastegui. (Author, 2018)

As a group, the class defines key characteristics of the site and building program to research. Rather than a broad overview, this research forms a constellation of factors. The Adaptive Assemblies must demonstrate architectural responses to both the composed materials and a selection of these key factors. Three Adaptive Assemblies -- a porous wall, a retaining wall, and a green roof assembly -- are modeled independently. Each begin as simple diagram where selected program and site areas of research are notated. Self-selected precedent projects aid the students in the development of architectural resolution of the assembly models. Success for these Adaptive Assemblies is measured through the design and communication of details (subsystems) that respond to the program and site opportunities prioritized.

At the macroscale, the interconnections are the spatial and circulation systems exhibited by the assemblies. The axonometric diagrams communicate each building system's response to various adjacency requirements. Emergent behavior in the spatial and circulation systems form as passive design strategies address alternate theater arrangements -- a Thrust, a Proscenium, and a Theater In-the-Round. The success of the axonometric diagrams is assessed in their ability to communicate the emergent behavior by the Adaptive Assemblies as they respond to spatial and programmatic requirements.

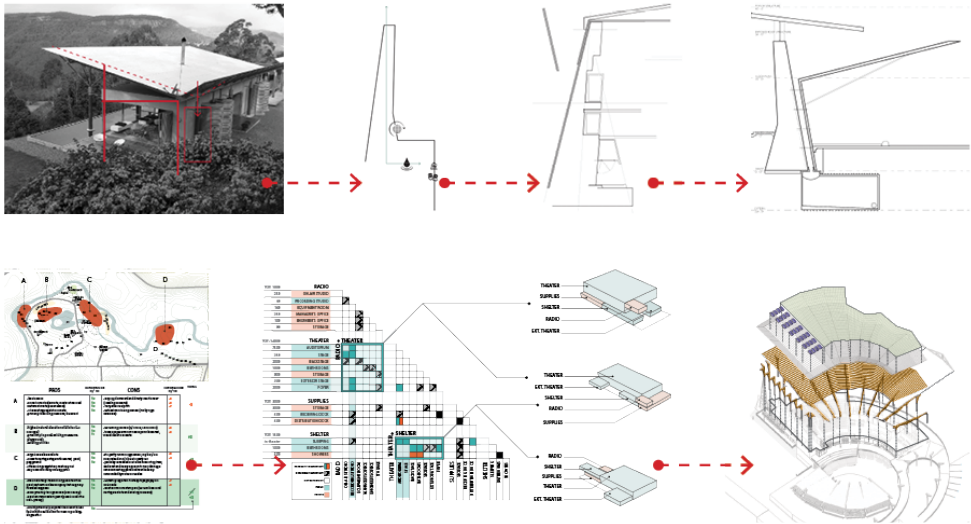


Figure 4. Development of an Adaptive Assembly, Student B. Ponvelle, E. Knapp. Emergent Ideas responding to context and program, Student (Author 2018)

Student comments on the Seeding Sequence:

"The layout of the course was different than past years but helped me develop a part of design I've usually lacked in the past." *Fifth-year Student 01*

"The instructor provided a unique method of teaching this semester that helped me understand the methods in which I was building and designing." *Fifth-year Student 02*

5.0. OUTCOMES

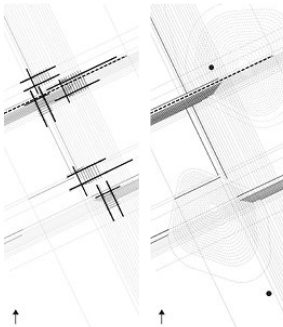
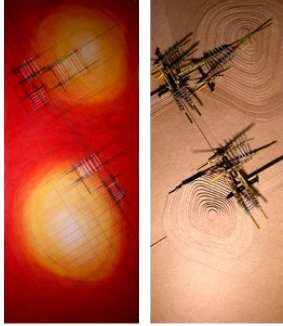
The Seeding Sequence design process presented in this paper, along with the student work and selected evaluations, demonstrate a design approach that relishes the complex nature of architecture and its design. In doing so, fundamental skills of self-critique were established while through a framework that facilitates today's focus on transparency and accountability of design decisions.

Was this Seeding Sequence successful withholding the designers' preconceptions of form and concept?

At both studio levels, the developed the Adaptive Assemblies first, specifically one that exhibits near-decomposability with nested subsystems, focused the students' attention away from preconceived ideas of form and concept of their final designs. As seen in nature's complex systems, this initial investment of design into the base unit level, allows complexity to emerge at the larger scale from the simplest of organizational strategies. In Beginning Design, with the deployment of only a handful of Adaptive Assemblies, the students witnessed their projects achieve a complex design response far beyond their design vocabulary. Although very complex, the logic established in the units remains legible, allowing for the reading and refining of novel design decisions. This sets a respect for design process, rather than a design epiphany. At the integrative studio level, with the Adaptive Assembly (wall sections) matured, each initial spatial adjacency scheme quickly communicates a complex layering of decisions. As the students' progress with the work, challenging the design to respond with greater sensitivity to programmatic and site opportunities, the emergent design ideas move the student's design responses far beyond a reductive concept.

Did the process actively question design decisions made in one method of investigation with those of another?

Beginning Design



Integrative Studio

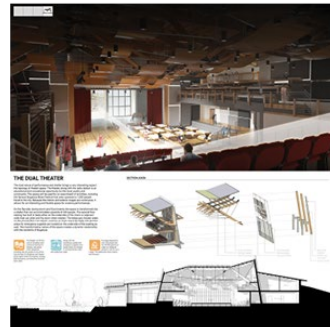


Figure 5. Final Project Beginning Design, Student XX (Author 2018). Final Project Integrative studio, (Student XX 2018)

Within beginning design, introducing the multimedia process drawing and Adaptive Assembly model making methods stages a moment when the student must come to terms that there is not a single correct method, tool, or digital program to design with. The student perceives how each method falls short in representing the others strength: The Adaptive Assembly model explores the design possibilities of the materials and techniques used in construction, whereas the multimedia Process Drawing nurtures a stronger understanding and evolution of formal organizational strategies. The Seeding Sequence pairing of two opposing methods, with dramatically different benefits and outcomes, establishes an awareness in the student to actively question what each new method brings to their design process. At the fifth-year level, the Adaptive Assembly Sections Drawings and Emergent Axonometric Diagramming focus the student on integrating professional communication skills into their design decision process. The rigor of the construction drawings as a means to express the design response to site and program through scale and tectonics while the holistic axonometric diagrams document the internal and external systems at play at the macroscale. The programmatic, environmental, and structural concerns that influence the initial axonometric diagrams lead to an evolution of the Adaptive Assembly section drawings. As the assemblies find resolution, the axonometric drawings can take on greater depth of systems integration. It is important to note that in both studio levels, the paired methods of investigation were selected by the instructor to challenge the skill level of the student and the required resolution of architectural design thinking for the course. Unlike Integrative Studio, where the methods are taken from the profession, it is important for the beginning design students to reflect that the drawing materials themselves are irrelevant. More importantly, is the ability to question how to think through the process of drawing.

How does the process demonstrate design response to the unique attributes of the materials, program, and site of the project?

Developing Adaptive Assemblies prior to establishing a general theory or concept, allows the student to make direct relationships between the architectural decisions at the assembly and sub-system levels that respond to the material, program, and site considerations. The

elimination of glue for the beginning design students' Adaptive Assemblies demands tangible response to the characteristic of each material used. Whereas the Integrative Studio's isolated approach to developing the Adaptive Assembly sections, allowed the student to focus on the design decisions relationship to the immediate human figure and site context. Once these design decisions have been embedded into Adaptive Assemblies, at either studio level, their deployment at the macroscale facilitates a general theory or concept to be drawn out of the emergent behavior. This bottom up approach allows the concept to form from the students' architectural design decisions, rather than a concept with which they struggle to find architectural resolution. Once identified, a deductive investigation of an emergent theory or concept focuses the design resolution with each recursive iteration of the two methods of investigation.

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- Conditions for Accreditation National Architectural Accrediting Board, Inc.

ENDNOTES

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- ⁱ (Dreamer, 2004)
- ⁱⁱ (Ockman, 2012)
- ⁱⁱⁱ (Lerner, 2005)
- ^{iv} (Klee, 1968)
- ^v (Johnson)
- ^{vi} (NAAB 2014)
- ^{vii} (Meadows 2009)
- ^{viii} (Mitchell 2009)
- ^{ix} (Meadows 2009)
- ^x (Simon 2002)
- ^{xi} (Box, Draper 1987)
- ^{xii} (NAAB 2014)