Building Technology Educator's Society

Volume 2019 Article 34

6-2019

Integrative Design and the Problem of Fragmented Knowledge

Dustin Albright
Clemson University, dalbrig@clemson.edu

Ufuk Ersoy
Clemson University, uersoy@clemson.edu

David Franco
Clemson University, francos@clemson.edu

Ulrike Heine
Clemson University, ulheine@clemson.edu

Integrative Design and the Problem of Fragmented Knowledge

Dustin Albright, Ufuk Ersoy, David Franco and Ulrike Heine
Clemson University

Abstract

During its 2017 NAAB accreditation, the School of Architecture at Clemson University received high marks for *Integrative Design*, having met this criterion "with distinction." The report stated: "*There was ample evidence… from the comprehensive design studios that students possessed the necessary abilities and skills to synthesize a broad range of contextual, design, and technical considerations into an integrated design solution…. The quality of the projects is high, which is in large part due to collaborative teamwork*." Undergirding the effective collaboration of the students, the Comprehensive Studio thrives on a careful schedule plus measured team-teaching from the faculty.

The Studio comprises 30-40 M.Arch students, working in pairs. The projects typically range from 30,000 to 60,000ft^2, and feature complex programs. The site and building design phases fill the first half of the semester, with the remainder focusing on technical development.

Overseeing this is a versatile team of instructors possessing professional experience and diverse expertise – from history/theory, to zero-energy design, to structural systems. This addresses, in a critical way, the notion of integration. Too often, the design studio is set up to recognize alpha designers, under the tutelage of the sage instructor. This leads to fragmented knowledge. Our approach instead emphasizes distributed knowledge while embracing ambiguity when it arises. On the one hand, the instructors' expertise is complementary, promoting robust, integrated design solutions. On the other hand, our critiques sometimes conflict, presenting a purposeful challenge and demanding that students carefully consider each position and chart a path forward. The projects are tested and refined by the process. This methodology has been honed over six years with decidedly positive outcomes and supportive student feedback.

This paper presents these methods and considers both the successes and challenges of directing integrative design studios in this manner. This analysis is supported with student samples and course feedback.

Introduction

The Graduate Comprehensive Studio at Clemson University is the concluding studio course in the M.Arch curriculum. It is required in lieu of a thesis.[1] The studio generally comprises 30–40 M.Arch students in their final semester, typically equating to three sections for the course. It is our practice to blend these sections and co-teach across the entire group. There is a single project spanning the entirety of the semester, and students work in pairs from start to finish.

The course's catalog description reads: "Architectural design studies addressing comprehensive building projects. Topics include site design, programming, building systems design and materials selection. Final product is a complete building design with detailed drawings and models." The broader objective stated in the syllabus is "to balance the extensive and complex technical, functional, and theoretical aspects of architecture with the creative and humane qualities of architecture."

Within our program, the specific NAAB student performance requirements (SPC's) assigned to the Comprehensive Studio are as follows:

> **B.3 Codes and Regulations:** Ability to design sites, facilities and systems that are responsive to relevant codes and regulations, and include the principles of life-safety and accessibility standards.
>
> **C.2 Integrated Evaluations and Design-Making Design Process:** Ability to demonstrate the skills associated with making integrated decisions across multiple systems and variables in the completion of a design project. This demonstration includes problem identification, setting evaluative criteria, analyzing solutions, and predicting the effectiveness of implementation.
>
> **C.3 Integrative Design:** Ability to make design decisions within a complex architectural project while demonstrating broad integration and consideration of environmental stewardship, technical documentation, accessibility, site conditions, life safety, environmental systems, structural systems, and building envelope systems and assemblies.

There are two corequisite courses, Professional Practice 2 and a course titled "Building Processes: Technical Resolution." These courses and the ways in which they dovetail with the Comprehensive Studio will be discussed later. A fourth course, Architectural History and Theory 4, is also completed at the same time, though it is not as explicitly linked to work of the studio.

History of the Comprehensive Studio at Clemson

The M.Arch program at Clemson University consists of a 6-semester track and a 4-semester advanced placement track. These two streams join in semester 3, with both cohorts being blended from that point forward. Semester 3 is highly structured, featuring a team-taught studio, Professional Practice 1, Research Methods, and Materials and Assemblies. Semesters 4 and 5 are considered "fluid" and invite students to study in one of our three off-campus programs. Students electing to stay at the main campus would take part in elective studios during that time. All students regroup on campus for semester 6 to complete the Comprehensive Studio and the other required courses mentioned above.

The evolution from a required thesis to the current Comprehensive Studio model involved multiple steps. Prior to 2005, all M.Arch students completed a thesis project over the course of their final year in the program. At that time, the "fluid" semesters, described above, occurred in semesters 3 and 4, leaving 5 and 6 for the thesis. During the 2005-06 academic year, an early version of the Comprehensive Studio was introduced as an alternative path to completion. The thesis technically remained an option in the graduate catalog (until 2010-11), but few, if any students elected to go that route. For the next couple of years, the Comprehensive Studio was held in semester 5, leaving semester 6 for a "Research Studio" in which course projects were linked to ongoing faculty research. The results of the Research Studio were uneven and it generally proved to be a disappointing way to end the M.Arch program. Eventually the Comprehensive Studio was moved to semester 6, where it remains today, and the Research Studio was later dropped.

Regarding the Comprehensive Studio itself, there was a series of structural improvements that led to the current format. Up until 2008, students worked individually on their Comprehensive projects. In the Fall of that year, they were instead teamed in pairs. This tended to lead to stronger work, primarily because it required internal collaboration. Beyond the questions and critiques of contributing faculty, each student now faced a steady stream of alternative ideas from their design partners.

This led to more vetting, reworking and, ultimately, refinement.

A form of co-teaching began in 2009, first with two faculty, and later with three in the years that followed. The instructors had each come from professional practice and were guided by their experiences of distributed expertise, modeled within their firms and across their relationships with project consultants. Thus, each took on the responsibility of contributing from her/his complementary knowledge base - from material exploration and methods of construction to passive energy strategies to structural systems. The quality of student work at this time (2010-2012) was notably strong, including numerous successes in student design competitions.

Fig. 1. Professors Heine and Ersoy, Spring 2018

However, significant operational challenges stemmed from the fact that there were still three distinct sections working on three different projects. At the time, the instructors (each in a tenure track) were encouraged to steer their sections' projects toward their individual research interests – perhaps as a holdover from the Research Studio. This approach, however, made it difficult for the instructors who, desiring to work together, had to keep up with each other's projects and evaluate students with consistency across a range of programs and scales. Beginning in 2013, the Comprehensive Studio moved to a true team-taught model, with blended sections and a common project. This general approach has remained consistent since that time.

Comprehensive Studio Faculty

Since 2013, there has been a steady cast of instructors for the Comprehensive Studio. Together, they draw from a diverse range of professional experiences and academic knowledge bases. For context, the expertise of each instructor is described below.

Ulrike Heine hails from Berlin, where she first specialized in highly technical, net-zero-energy design. Among other things, she contributes knowledge in balancing passive design strategies with well-tuned mechanical systems. Professor Heine served as coordinator for the Comprehensive Studio until 2015, when she assumed the role of Assistant Director in the School. Dustin Albright, from the U.S., possesses a dual background in structural engineering and architecture. A licensed architect, Professor Albright has worked professionally on a wide array of project types, with particular interests in structural systems and building tectonics. He has served as Comprehensive Studio coordinator since 2015. Ufuk Ersoy, hails from Izmir, Turkey, and practiced and taught internationally prior to arriving at Clemson. He teaches in the area of architectural history and theory, with a particular interest in metaphorical thinking and the role of memory in architectural imagination. David Franco comes from Madrid, where he practiced for many years. In addition to teaching materials and methods courses in the School, he teaches in the area of history/theory. His scholarship revolves around the social and political aspects of modern and contemporary architecture. Professors Ersoy and Franco have tended to teach the studio in alternating years, with Professors Heine and Albright teaching every year.

Supportive Courses

The first of the co-requisite courses, Professional Practice 2, covers NAAB SPCs B.3 (Codes and

Regulations), B.10 (Financial Considerations), D.1 (Stakeholder Roles in Architecture), and D.4 (Legal Responsibilities). It is structured around the topics of zoning regulations, building codes and cost analysis. These lessons are applied throughout to each student's Comprehensive Studio project. Products include a site and zoning plan, a life-safety plan, and a detailed estimation of project costs.

The second co-requisite course, "Building Processes," operates as a technical support seminar to the Comprehensive Studio. It addresses SPCs B.4 (Life Safety), B.5 (Technical Documentation), B.6 (Environmental Systems), B.7 (Structural Systems), B.8 (Building Envelope Systems), and B.9 (Building Service Systems). Lectures on these topics and their integration within architectural projects are presented during the first half of the course. The second half involves application to the Comprehensive Studio projects, during which time the "Building Processes" instructors act as technical consultants to the design teams. This coincides with the technical resolution phase of the comprehensive projects, described in the next section.

The Comprehensive Project

The projects selected for the Comprehensive Studio tend to fall in the range of 30,000 to 60,000ft^2. They feature complex programs with multiple uses. Some examples from past years include: a live/work development, a performing arts center, a university student center, and, most recently, an urban high school (in 2017), and mixed-use graduate student housing (in 2018). In each case, a base program is provided as a starting point. Students are also invited to propose program additions, provided that they are well-conceived and defended. In the case of the high school, for example, students were challenged to think of programming that could double as after-hours community amenities – such as maker spaces, gym spaces, cafés, etc.

Project locations are almost always within a 3-hour driving distance from our campus, providing the class with opportunities to visit and get to know the context. Typically, students are given choices of specific sites within the larger location. For example, in the case of the high school, students were provided four potential sites within the fabric of downtown Anderson, South Carolina. These sites were preselected by the faculty according to considerations for access, available footprint, and the potential for the new school to complement and/or reshape the spatial and programmatic structure of its setting. Students then begin with a detailed analysis and selection of site. Wild card sites are sometimes permitted if the students make a compelling case.

Project Sequence

The sequencing and pacing of the project, along with the timing and manner of critical feedback from the faculty, have proven to be decisive forces for project success. Broadly speaking, the semester is divided into two predominant phases: initial project design and technical development. In order for students to achieve the level of technical depth required by the course and its associated SPCs, the instructors have found it essential to allocate a third of the course schedule for the resolution of technical systems (structural, environmental and envelope), prior to final documentation. This means that the earlier design sequence (site analysis, programming, building planning and design) must be entirely completed during the first half of the course.

This pace can be jarring for students, who are generally unaccustomed to making resolute design decisions so early in a project. The structure of the course deliberately accelerates analysis, ideation and response, preventing participants from languishing uncommittedly between concepts. The decision to have students work in pairs is particularly helpful at this juncture. Whereas the extra set of hands makes practical sense for increasing productivity in the later documentation stages, the partnership serves to generate internal discussion and fruitful criticism in the early design stages.

Within this overarching framework, there are numerous intermediate stages and deadlines, set to motivate intensity of focus, and to keep the projects on track. Each of the stages is described in detail in the following section. For clarity, the urban high school project from 2017 will serve as a reference point throughout.

Stage 1: Site Selection, Analysis and Concept Forming (2-3 weeks)

Upon introducing the project, the Studio jumps into detailed analyses of the available sites and comparisons of their challenges and opportunities. In the case of the 2017 project, students tackled this first step in larger teams of five or six, traveling together on the first afternoon to the city of Anderson, less than 20 miles from our campus. In this case, site studies addressed topics of adjacent uses and vacancies, parking and parking utilization rates, established pedestrian routes, traffic and noise, etc. The student teams shared their analyses and their preferred site (from among the four suggestions) during a presentation the following studio period.

Fig. 2. Analysis of existing parking (by Kaylan Betten and Amelia Brackmann, 2017)

It is also within these first couple of meetings that the Studio is introduced to any external project partners, who often serve as advisors and critics throughout the process. In this case, we welcomed an arts teacher and an administrator from an innovative local high school[2] who described their unique project-based learning model and its implications for their facilities and operations.

In the following week, the Studio works through initial programming and spatial design concepts, working now in pairs. As a base program for the 2017 project, students were given a list of required program elements (classrooms/labs, media center, dining, assembly hall, health clinic, administration, and support) and provided a reference program (including space allocations) from an existing high school in the area. As mentioned above, students are given license to propose program additions and/or hybridizations, as may benefit the project.

It is customary for studio faculty to divide up at this stage and meet individually with the student pairs. This ensures that every group receives ample time with instructors during each studio session at this early juncture. Instructors then rotate from session to session, seeing different projects on successive days. This introduces each instructor to the whole range of projects while also providing each design team with multiple perspectives on their foundational concepts and actions. Often, the comments of the faculty align and reinforce each other. Sometimes, the comments are in conflict. This possibility is embraced by the instructors (though it sometimes frustrates the students) because it requires a process of critical thought and interpretation, wherein teams must adopt one path or the other, or perhaps chart a third way. In any case, their response tends to be well-considered, and projects are generally improved through this tension.

Fig. 3. Conceptual program organization (by Kaylan Betten and Amelia Brackmann, 2017)

The initial project concepts are presented in a first formal pin-up during the third week. Students are often encouraged to present multiple schemes at this stage and lead a discussion of each scheme's merits relative to programmatic objectives and site parameters.

Stage 2: Massing and Building Planning (2-3 weeks)

The second stage picks up with site design, building planning and massing studies. Students negotiate topographic conditions, issues of scale, orientation and circulation through iterative massing models. These are performed in parallel with initial plan and section drawings. Student teams explore precedent projects, often receiving particular guidance from Professors Ersoy or Franco in areas ranging from typological studies to urban design theory.

The course faculty continue to meet individually with students, rotating from session to session, as with the earlier stage. Occasionally, they will team up to meet with any students who are falling behind or struggling with some aspect of the project. In these cases, the instructors are able to efficiently gauge the project's status, and together recommend next steps to take and a schedule by which to take them. This way, each instructor is on the same page and knows what, specifically, to be expecting in subsequent meetings with these particular teams. The work from this second stage is again presented in a formal pin-up.

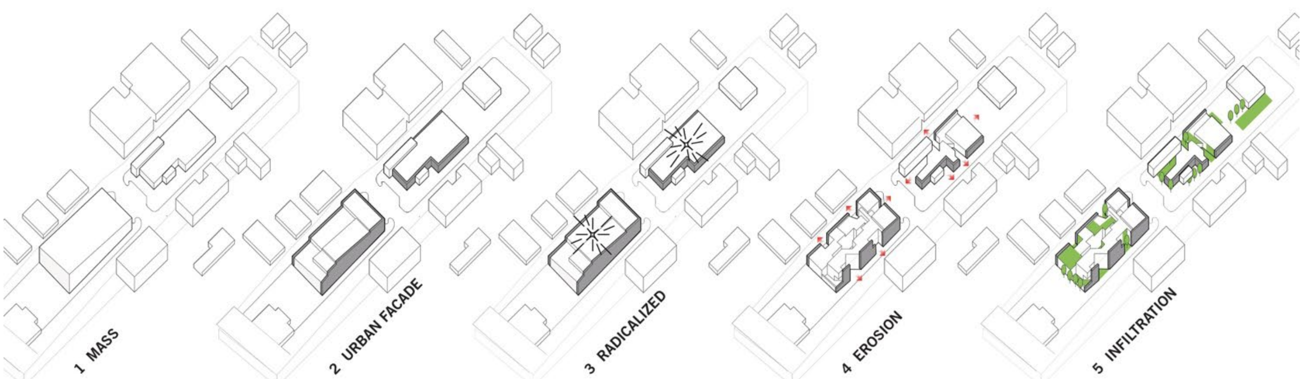

Fig. 4. Building massing diagrams (by Kaylan Betten and Amelia Brackmann, 2017)

Stage 3: Final Schematic Design (2 weeks)

Next, students are allotted a couple of weeks to refine their site and building designs. The floor plans and associated sections are closely evaluated at this stage. They are appraised for efficiency (in circulation, in the stacking of wet functions, etc.), and for issues of life safety and accessibility. It is at this time that the projects undergo a detailed plan review with a building code official in the accompanying Professional Practice course.

The designs are examined broadly for load path continuity, bay size, improbable overhangs, and other early structural issues that may have immediate implications for the plans. Professor Albright tends to advise in these discussions. The projects are likewise evaluated, at a schematic level, for adequate daylighting and appropriate shading. Professor Heine takes a leading role with passive design strategies and helps teams premeditate synergies with their eventual mechanical and lighting systems.

Stage 3 concludes with a formal pin-up. Outside critics are welcomed in at this point, including any project partners. Colleagues from Landscape Architecture are often included for their input on site design. Importantly, this review marks the cut-off point for the overarching "design" phase. Students are given the remainder of the week and weekend to respond to critics' remarks and make any necessary revisions to their projects. Beyond that point, the Studio moves into its extended period for technical development and resolution.

Stage 4: Technical Resolution – Structure (1 week)

The first of the technical resolution stages focuses on structural systems. One intensive week and weekend is allotted for this work, and, under the direction of Professor Albright, students are required to produce three coordinated deliverables. The first is a scaled physical model of the entire structural frame. This forces students to visualize the systems in three dimensions, identifying primary, secondary and, sometimes, tertiary components. They evaluate direction of flooring/roofing systems and lay out appropriately spaced supporting members. The model quickly exposes any discontinuities in their planning. It also provides an excellent vehicle for discussions of lateral force design. Finally, it forces students to tackle any unique challenges presented by the massing. It is stressed that these models are working models, intended to be modified with each successive consultation.

Stemming from the model, the second deliverable is a set of structural framing plans for each level, plus ground floor foundation plans. Students are not asked to calculate member sizes. Instead, the course's required reference text helps with general estimations of slab thicknesses, beam depths, and column dimensions, while also providing a good overview of the material systems at work.[3]

The third deliverable is a set of structural diagrams articulating load path and system hierarchy. Building upon the physical model, this last requirement ensures that students understand the system at a deep level, to the point that they can illustrate how it is really working.

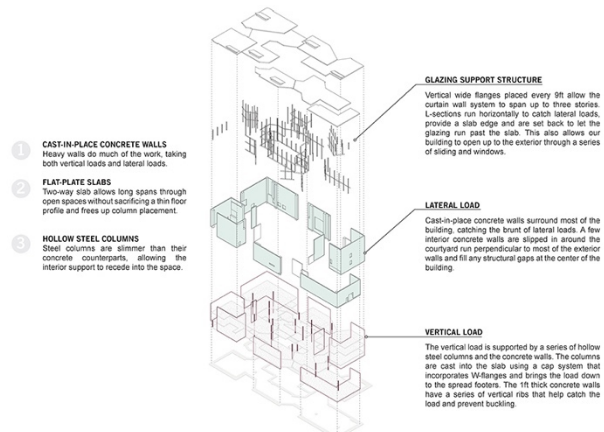

Fig. 5. Structural hierarchy diagram (by Kaylan Betten and Amelia Brackmann, 2017)

The rigor of the structural resolution stage is particularly critical in light of the fact that many of our 2-year M.Arch students will not take dedicated Structures courses in our program. Instead, they bring with them the equivalent courses from their undergraduate institutions, which often vary in quality. Moreover, it may have been many years since a given student completed these undergraduate courses. Such differences in comfort and proficiency are discernable each year, and the structural stage of the project provides the chance to iron out some of the wrinkles.

Unlike the earlier stages, Studio faculty tend to visit with student teams together at this point and for the remainder of the technical resolution work. This ensures that students are receiving coordinated advice on the finer points of the projects. Some discrepancies can arise at these stages from the consulting instructor(s) of the "Building Processes" corequisite, whose consultation times fall outside of the studio sessions. It is incumbent upon both course's faculty to maintain good communication throughout, and that students learn the pros and cons of any competing technical solutions.

Stage 5: Technical Resolution – Environmental (1 week)

Following structure, the next stage focuses on environmental systems. Here, students are required to select and lay out appropriate HVAC solutions. Again, they use the course text to help with selection and approximate sizing of mechanical equipment and ducting. Professor Heine works with students to integrate their earlier notions of passive ventilation, where appropriate, and each team is required to produce mechanical plans plus detailed spatial diagrams communicating the circulation of air, or water, in the case of radiant systems. Students are required to confirm that ductwork is not in conflict with the structural systems laid out in the previous stage. In some cases, this requires reevaluation of one or both systems. Importantly, all M.Arch students complete a required environmental systems course in the preceding academic year, and so are prepared with a fundamental knowledge. That being said, the comprehensive project provides the first real design application of this knowledge.

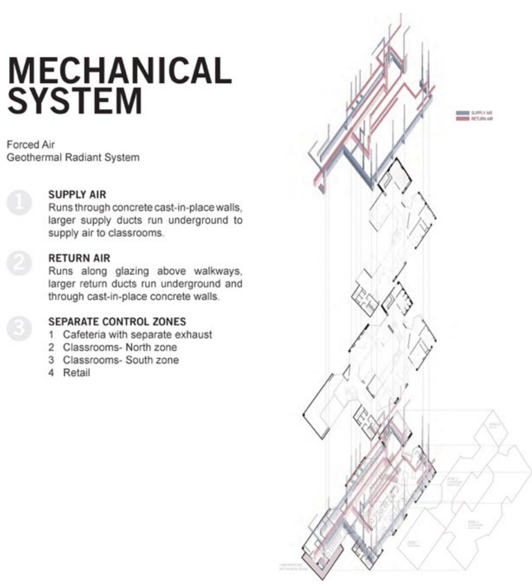

Fig. 6. Mechanical system diagram (by Kaylan Betten and Amelia Brackmann, 2017)

Stage 6: Technical Resolution – Envelope (2 weeks)

The development of the building envelope occupies the final two weeks of technical resolution. At this stage, the collective professional experiences of all the studio faculty come into play, and all are equally involved in advising students. Student teams are generally required to produce at least three annotated wall sections, typically ¾" = 1ft in scale. Each section must extend from the foundation to the roof, and any window or door openings should be emphasized. Additional sections at a larger scale are often required to capture the finer details.

Design teams will go through multiple iterations of the wall sections, printed out and marked up during each studio session. Customarily, each team member will be required to author at least one of the drawings, ensuring that both partners have mastered the content. This is one measure taken to prevent partnerships from devolving into siloed work under the pressure of producing within a tight schedule.

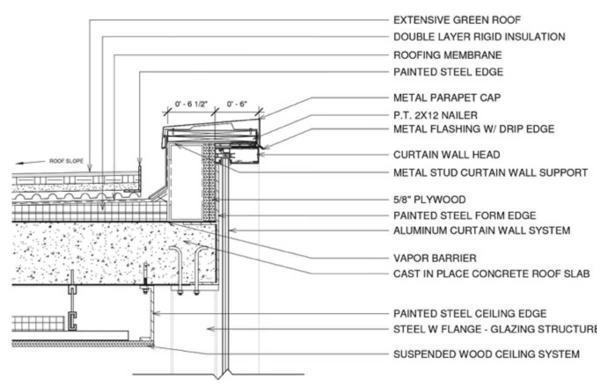

Fig. 7. Section detail drawing (by Kaylan Betten and Amelia Brackmann, 2017)

The section drawings, as one might expect, end up being potent demonstrations of integrated design. Structural and mechanical systems are depicted in concert with the envelope solutions. Daylighting strategies come into focus, as do considerations for acoustical treatments and other finishes. The degree to which building systems are displayed or concealed must be considered. With every element depicted comes a web of connected decision-making.

Stage 7: Comprehensive Examination (1 week)

On the heels of the technical resolution stages, and as a way of demonstrating a deep and cohesive knowledge of the lessons learned, students are required to pass an oral examination. This takes the form of a closed presentation made by each project team to a faculty panel, including the studio instructors and, often, the instructors of the corequisite courses. The points of emphasis for this presentation align directly with those outlined in NAAB SPC C.3: "environmental stewardship, technical documentation, accessibility, site conditions, life safety, environmental systems, structural systems, and building envelope systems and assemblies." Each of the models, diagrams and drawings prepared in the technical resolution stages, along with the site and building plans themselves, takes a prominent place in the examination process, and students are required to speak with clarity and accuracy about their choices. In lieu of a thesis, this serves as a sort of defense of the work, and the process acts as a formal gateway for graduation.

Student teams are advised in advance that each member should be conversant about all aspects of the project, and may be called upon at different points to speak on their own. Naturally, students will divide and conquer on project tasks – such is the nature of working efficiently toward design goals. However, the course, and the degree, requires that every student develop and demonstrate comprehensive and integrated knowledge. The manner in which the faculty administers the oral examination, therefore, requires careful attentiveness to team dynamics and provides another check against specialization and siloed knowledge within the project.

Stage 8: Refinement & Final Documentation (2-3 weeks)

Following the successful completion of the Comprehensive Exam, students are allotted an extended period for any final revisions and for final, polished documentation of the project. This is in preparation for the final project review. Distinct from the exam presentation, the final review is open to classmates, external critics, and any project partners. An emphasis is placed on presentation drawings and rendered images, as well as final site models and a detailed wall section model. This latter model, often scaled at ½" = 1ft, serves to cement for the students the interoperability and the tectonic qualities of the various systems at work. Students must reach back and recall the guiding premises from the project's early stages, and recognize their imprints on the resolved, constructed solutions. Is the project self-consistent intellectually and technically? This is, after all, the ultimate litmus test for integrative design thinking.

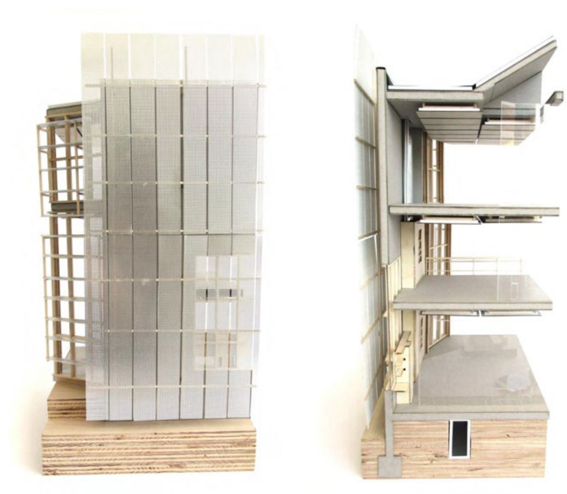

Fig. 8. Wall section model (by Kaylan Betten and Amelia Brackmann, 2017)

Student Assessment

Beyond the anecdotal pride in their accomplishments and appreciation for the substance of the work, students' formal assessments of the course have been remarkably positive. Specific to the course structure, 93% of respondents in 2017 and 92% in 2017 rated the course as very-well organized.[4] The average ratings were, respectively, 4.93 and 4.92 (out of 5). This compared to averages of 4.30 and 4.02 among other classes within the discipline and at the same level.

Regarding the co-teaching of the course, students routinely offered comments such as: *"I firmly believe all three professors are strong assets…. Each one brings a unique background and a wealth of information to the course. Without their personal and professional insight, I know my work wouldn't [have] reached the level it was able to."* And, *"Very well organized, [the instructors] each bring a different perspective and different strengths to the course."*

Noting the challenge of receiving conflicting feedback, some students expressed frustration: *"Desk Crits when all three would be together would be most helpful. When they would split up, sometimes the three different directions given would be conflicting."* Others saw the value, affirming the underlying intentions of the faculty: *"Contradicting ideas sometimes can get confusing but it's the responsibility of the student to choose where to take the different ideas."* And, *"All three professors worked very well together. At times, they would give different opinions that would help to give a broad spectrum of feedback, which created a better project in the end."*

Students were generally positive about the pace of work, recognizing the rigorous demands of the course. In conjunction, some expressed a desire for greater cohesion between the studio projects and the corequisite courses: *"I really enjoyed the notion of the [Studio] course working with the 2 other courses... It made the workload a lot easier... But I believe there is some refinement that still needs to be worked out. At the start of the semester it just seemed like studio was a week ahead in comparison to the other classes that were linked to the project."*

Conclusions

The methodologies of the graduate Comprehensive Studio at Clemson University have been important contributors to strong student work that consistently demonstrates excellence in integrative design. By placing the technical stages on equal footing with the earlier design stages, a clear message is sent regarding the limitations of ideation without deep development and execution. Furthermore, through its structured commitment to collaboration, among student partners and among the instructors, the course recognizes distributed knowledge as a necessary foundation for integration (and deterrent to fragmentation).

Reflecting on the strengths of the current approach, the course faculty point to their own diverse backgrounds which lead to open and honest conversation, in which the technical aspects of the project become questions to debate rather than certainties to be transmitted to the students. This process, and the length of time afforded for technical resolution, makes it possible to develop the technical aspects creatively, not as a mere problem-solving process, and it also contributes to great diversity in the architectural outcomes. The faculty report greater personal satisfaction from working together in a dialogue, though they recognize that co-teaching demands more front-end preparation and organization.

Relative to the pairing of students, one underdiscussed benefit is the flexibility for individuals to dig into whichever aspects (formal, material, etc.) or skills (model making, technical drawings, etc.) they are most interested, without diminishing the scope of the project. However, this positive can become a challenge, if unchecked and students are allowed to disentangle themselves from the integrative work. The teamwork can likewise present a challenge to employers who, while recognizing the inherent value of collaboration, report difficulty in discerning the specific contributions of individual students.

Reflecting on other downsides to the current approach, faculty note that the rigors of the schedule do somewhat limit the scope and depth of conceptual questions in the early stages. The faculty also agree that greater coordination needs to take place across the schedules of the corequisite courses. While these courses undoubtedly contribute to the successes of the Comprehensive Studio, their potential has not been fully tapped.

Notes:

1 There is still a thesis option within the healthcare design specialty in the School of Architecture, though most students in that program also opt for the comprehensive project.

2 The NEXT High School is a public charter school in Greenville, South Carolina. It offers an alternative, project-based curriculum that has drawn praise in education circles. A project-based learning (PBL) approach was required for the 2017 design proposals.

3 Allen, Edward and Iano, Joseph. *The Architect's Studio Companion: Rules of Thumb for Preliminary Design.* Wiley: Hoboken, NJ. 2017.

4 These figures are based upon a 64% survey participation rate in 2017, and a 79% rate in 2018.