Prefabrication as the Comprehensive Studio

Introduction

Most architectural programs utilize the comprehensive studio as a method of demonstrating that architectural students can synthesize their support and studio courses into a fully resolved architectural design project. Traditionally however, the focus of the comprehensive studio is not design innovation; instead the studio is a checklist, verifying students can integrate a variety of criteria into a final design. Unfortunately, this methodology gives architects little chance to explore new building materials and assemblages, or innovative solutions to the building systems. In order to position future architects to influence new technological architecture directions, we need to reconsider the comprehensive studio’s standard practices and problems. We need to introduce non-traditional studio problems that encourage innovative design solutions.

To this end, I developed a comprehensive studio that utilized prefabrication technologies and building production as the given studio problem. As opposed to the traditional comprehensive studio where the building systems are overlaid onto the architecture design, the prefabrication studio directly integrated the design of the structure, systems, and assemblage with the architecture. Because solving the system of assemblage, transportation, and site erection were part of the given problem, students were able to directly link the making of the object with the object’s design. In comparison to the standard comprehensive studio, benefits of and skills learned through this studio included: exploring innovative materials and building assemblage processes; designing the building core and connecting the core to site services; and addressing the design interface between site-built and factory-manufactured building tolerances.

This paper will contrast the comprehensive studios typical in most architectural programs and with the comprehensive studio that I developed as a professor at the Savannah College of Art and Design (SCAD). This paper will describe the comprehensive studio goals and outcomes, and will demonstrate how prefabrication as a studio problem enhanced the student’s experience within the comprehensive studio. Projects that developed as a result of this studio were well researched, considerate of building systems and utilized innovative materials and building assemblage practices as a demonstration of architectural expression. I believe that by providing an architectural problem—such as prefabrication—that requires innovation, future architects will be better positioned to shape architectural research in the 21st century.

The Comprehensive Studio

To begin, we need to investigate the comprehensive studio as a studio typology. The comprehensive studio, sometimes referred to as the capstone studio, represents a culmination of all that students have learned throughout their architectural education into a single design solution. The intent of the comprehensive studio is to coalesce the students’ design skills from studio with information learned through their support courses (environmental controls, structures, construction technology, acoustics, and lighting). Final projects for this studio typically ask students to produce a building that demonstrates an understanding of building structure, plumbing and electrical services, heating and venting systems, building assemblages, and sustainable practices. For most programs the comprehensive studio occurs at the end of a student’s education. Support courses are either completed before the comprehensive studio (as is the case at SCAD and the University of Notre Dame) or are taken in conjunction with the comprehensive studio (as is the case at Catholic University of America, University of Maryland, and Philadelphia University).

The National Architectural Accrediting Board (NAAB) does not describe specific requirements for the comprehensive studio, but individual accredited programs assign a number of student performance criteria to be
addressed through this studio. The comprehensive studio is a design studio and so some of the assigned criteria (e.g., Critical Thinking Skills, Graphic Skills, Research, and Fundamental Design Skills) are similar to other design studios. Although the overall student performance criteria for this studio vary from program to program, there appears to be a criteria group that is universal to the comprehensive studio. These criteria include: Site Conditions, Structural Systems, Life Safety Systems, Building Envelope Systems, Building Service Systems, Building Systems Integration, Building Material and Assemblies, and Comprehensive Design. Because of the sheer number of student performance criteria that are required by individual program's comprehensive studios (SCAD lists seventeen), this studio type is often required to address more criteria than any other studio within that program.

The comprehensive studio is often seen as a student's closest experience to practice and follows the standard building design procedure of many professional offices. Through this studio, students progress through conceptual design, schematic design, design development, and then to documentation. In the beginning, students may study building form, but as the design quickly develops they investigate building structure, building services, and the building assemblage. Eventually, the systems interface with the design, allowing the students to resolve the building into a comprehensive solution.

I believe that the traditional comprehensive studio has been problematic for many reasons. First, the opportunity for resolution is difficult because of the academic calendar's limited time frame. An office often utilizes a team of architects and consultants for more time than a standard sixteen-week semester, thus offering many more person-hours than a student has available. The second problem with this studio is the perceived lack of design rigor. Because of the time necessary for the design resolution, little time is spent on conceptual and schematic design. As a result, design suffers and the "comprehensive" portion of the studio is seen as the necessary but uncreative portion of the studio effort. Next, because the comprehensive studio follows the traditional professional design process, students see the systems portion of the design as being subservient or reactive to the design process. The art of building design is seen as separate and superior to the craft and beauty of a building's reality. Finally, because the performance criteria for this studio are so extensive, student workloads are necessarily focused on building resolution rather than building innovation. Therefore traditional services and systems are used in the design solutions instead of proposing new and innovative solutions.

It is my assertion that design problems and studio organization for the comprehensive studio need to be better configured. We need to emphasize that the design of the building systems can be as creative as the conceptual design of the building itself. In addition, I believe that the studio can continue to coalesce all that the student has learned within a singular studio, while at the same time offering students a more creative design process. Students can also utilize the comprehensive studio as a testing ground to develop new materials, building assemblages, and innovative services. In order to create an environment in which the students could explore all of these elements, I believed that the studio problem needs to be small in size to allow for exploration and invention, but complex enough to address the studio typology. This is why I created the design problem of a prefabricated house and required that the house be kept to less than 1500 square feet.

Prefabrication Studio

To address the perceived lack of design rigor associated with the comprehensive studio, the studio was conceived so that design was extended beyond a theoretical aesthetic argument to include the beauty of the building systems. Emphasis was placed on the design of the core, building structure, and assemblage, and how those items enhanced, or directed, the building's design. This emphasis was done through assigned theoretical readings, a created studio culture, and a new design process. Students were asked to begin designing by investigating their building core and work outwards towards the building shell. The beauty of the student's designs were not in the overall shape making of the project, but became about the articulation of the building through the design of its structure, plumbing, HVAC, materials, and building assemblage.

By asking the students to design a prefabricated house, students considered the building systems in a manner that they had not
been previously accustomed and this led to greater understanding and innovation within their designs. We concentrated on the questions of how the building would be assembled and how it would operate. The studio focus was on the issues of prefabrication but also included the production of the architecture. Initial studio assignments focused on the link between design and making and then through later assignments students developed a business-plan that created their consumer market and directed their building program and aesthetic choices.

For an assignment titled “Consumer Mapping” students specified a geographic region, a consumer profile, and deployment scenarios for their proposed prefabricated unit. The selected geographic region established a shipping-radius from the fictional manufacturer, identified a potential market, and recognized potential sustainable practices through the researched area’s macro-climate. As students developed consumer profiles for their prefabricated house purchasers they outlined specific characteristics of the consumers’ lives including annual salary, current housing stock, profession, age, recreational activities, hobbies, and frequented stores. The intent was to establish common purchasing characteristics among the consumers and to direct the students to a building program and potential design aesthetic. The consumer mapping exercise also guided students in creating deployment scenarios for their prefabricated houses. For example, if the student selected the Northeast corridor as his or her geographic region, high land costs would necessitate the design of stacking the prefabrication houses for better financial development. This deployment scenario would be different from the South’s land to cost ratio where each house could be situated horizontally. How the prefabricated houses were transported and erected on site would also be considered as part of this assignment.

Because of the project’s intentional small size, the services within the house are a dominant feature of the building design. The dominance of the building core reinforced the importance of the building services in the students’ designs. The core housed the areas of food preparation and personal hygiene, and included utilities such as a water heater, an electrical panel, and heating and ventilation as necessary. According to the project brief, the focus for the core’s design “is to be on the resolution of the organization, practicality, materials, serviceability, and dignity of the core.” Students were asked not to simply design the core based on haptic aesthetics, but instead the beauty of the project would be seen in the study and the design of the core’s systems. Students were challenged with not merely addressing how the plumbing would be organized; instead they were asked to design the core based on the best method for organizing the plumbing.

Large scaled study models at 1"=1'-0" were required for each student’s design. See Figure 1. These models allowed students to better understand and manipulate the systems (e.g. plumbing, electrical, and HVAC) within their core. Students demonstrated how the services would interact with each other and they designed the core so that their core’s systems had direct spatial implications on the rooms themselves. The large-scale models also necessitated a certain amount of detail, demanding that students illustrate plumbing supplies and waste, electrical pathways, heating and/or venting systems, and any other supplemental or sustainable systems to be included within the core. Students were also asked to coordinate those services with the core’s structure, ensuring that the systems

Fig. 1. Large-scale study models of building cores. From left to right: Jessica Young and Luke Helkamp
would be integrated with the building assemblage components.

Since the houses were designed to be manufactured, the prefabricated house had a potential for a substantial production run. It could be imagined that with a large production run, building elements could be easily customized. Because of this, students could explore new territory for their design. For example, students would be no longer restricted to design a bathroom with standard toilets, sinks, and tubs; instead since everything would be mass-produced, the design of the bathroom and kitchen could be completely customized without the traditional associated added costs. Students could re-conceptualize not only the fixtures, but the very notion of the bathroom itself. They were no longer limited to those items previously associated with housing (i.e. conventional framing, standard fixtures, etc.) but could now explore new possibilities of technology, materials, and services. Through the design of this comprehensive studio prefabricated architecture was not seen as limiting in terms of design, but was now seen as expansive.

Fig. 2. Core design proposals for prefabricated houses. Images of core are not to scale. From left to right: Scott Blew, Katie Irons, Luke Helkamp (kitchen component with HVAC units highlighted), and Laura Denton (electrical services are in orange and plumbing services are in purple).

Since students were not limited to standard systems and traditional materials, they evolved new notions of the bathroom and kitchen. See Figure 2. One student, Scott Blew, proposed a design that offered a condensed bathroom layout where the sink, toilet, and shower spatially overlapped and that the sink would have to be folded up into a recess in the core wall in order to use the toilet. He conceptually designed the retractable sink so that the waste water would drain through the hinge. When the sink was left down, the mechanics of the hinge would cover the drain, thus eliminating the need for a plumbing trap. His compact design of the fixtures allowed the entire bathroom to fit into less than 10 square feet, greatly reducing his building footprint. Some of the students investigated new materials for their building core. Blew proposed fabricating his bathroom out of injection-molded plastic. He incorporated the plumbing system directly into the injection-molded plastic fabrication process, eliminating the need for a separately assembled plumbing system. Another student, Katie Irons, proposed constructing her prefabricated house out of molded fiberglass, constructing the bathroom walls and fixtures out of a single mold. This eliminated any joint work within the bathrooms, therefore reducing potential shifting during transport and improving cleaning and maintenance of the core.

To stimulate conversation, the studio read Refabricating Architecture by Stephen Kieran and James Timberlake. We discussed manufacturing technologies and how those might revolutionize the architectural construction industry. Students were challenged with thinking about the different trades perhaps working simultaneously within the manufacturing process, and began to envision ways of isolating those trades’ work from one another. Perhaps one wall, or only one portion of the wall, would house the electrical services, while another wall would be servicing the core’s plumbing systems. In contrast, some students chose to overlap their services in an intricate manner. Their argument for overlap was that since the items were manufactured within a factory under one company’s work effort, it would become easier to coordinate among the trades especially in comparison to a stick-built house. Either of these construction approaches allowed the core or portions of the core to be fabricated in what Kieran and Timberlake refer to as “chunks” and
could be potentially subcontracted and constructed off-site from the factory. Both of these approaches are demonstrated in Figure 2. Laura Denton, in her dynamically shaped building core, took great care in separating her core’s services. She identified separate physical pathways for the electrical and plumbing components. The electrical pathways would be located in the building’s structural frame while the plumbing pathways would stem directly off of the building’s cylindrical structural and plumbing core. Luke Helkamp designed his core to be split, so that the kitchen and bath would be located on and supported by opposite ends of a structural frame. (Helkamp’s conceptual model was documented in Figure 1.) Helkamp’s premise had been that the core could be external to the building structure and its components could be customized. Both the bathroom and the kitchen contained the electrical, plumbing, and HVAC services to the building and distribution of those services were coordinated through the building’s structural frame. Helkamp conceptualized the prefabricated process as one company that would employ and coordinate a number of different trades to manufacture a well crafted, albeit complex, building. Both of these projects have the potential for outsourcing building components other factories, with the potential of the supporting frame, the core casings, or the plumbing and electrical services, being manufactured by highly specialized subcontractors. We could also extend this idea of outsourcing to Blew’s core. His core was not organized as separately constructed chunks, but the core itself could be constructed by a singular manufacturing process and then incorporated into a variety of applications including traditionally stick-built homes.

From the building core, students worked outward towards the skin of the house. Students continued to offer inventive materials and new assembly processes for their house’s exterior construction. See Figure 3. Returning to both Blew’s projects, his innovative use of plastic extended beyond the core and included the overall building enclosure. Utilizing extruded plastic for the building skin and structural system, Blew designed a truss system in the floor and roof of the unit that could be directly manufactured through the process of extrusion. He also incorporated a gentle slope to the roof to shed water and designed the interior surface to form continuous shelving. The open ends of the structure would then be capped with a customized storefront system. Adam Jordan investigated the potential of cannibalizing decommissioned commercial airplanes to construct his prefabricated structures. Jordan researched airplane stress-skin structures, and proposed how those structures could be sectioned from a plane and re-assembled into
a house. He proposed the design for new structural connections between the plane’s wall panels and connections between the wall panels and a new proposed floor.

Some students’ design proposals included standard building materials to construct their prefabricated house, but utilized those materials in a non-traditional manner. Chae Carlson designed a two-story prefabricated house that would be constructed from wood studs. Because of the United States Department of Transportation’s (USDOT) restrictions on shipping sizes, her house was required to be constructed of a minimum of two modules. During the beginning of the project, she designed a vertical core for her house, so that the bathroom and the kitchen would be stacked. She wanted to maintain all plumbing and HVAC services within only one module to greatly decrease the number of complicated on-site connection work. Because of this self-imposed design decision and the USDOT’s size restrictions, Carlson proposed that the two modules be divided vertically instead of the traditional horizontal division. To tectonically support the vertical division, Carlson proposed using balloon framing instead of traditional platform framing, allowing the studs to be continuous throughout the module’s construction.

Helkamp had proposed fabricating his building’s structural frames out of extruded aluminum. The hollow frames could be equipped with the building’s electrical and plumbing services as well as provide supply and return channels for his HVAC system. His structural frames would attach to a precast foundation system and could accept a variety of customized wall assemblages. His sloped roof structure would be constructed of extruded plastic and would be mechanically fastened and gasketed to the structural frame. Structural insulated panels (SIPs) would be used for the building’s floor system.

Because the studio focused on prefabrication, students addressed not only how the building would be assembled in the factory, but also conceived of how the house would be assembled on site. As part of the final presentation, many students presented a filmstrip or an animation of their proposed on-site assemblage sequence to demonstrate how the buildings could be erected. See Figure 4.

Returning to Irons’ fiberglass core, her material selection extended beyond the core and included the building’s structural frame. She designed her prefabricated unit to service hurricane and other national disaster victims housing needs, and so needed a unit that would be light, compactly transportable, and
Fig. 5. Construction tolerances between factory-manufactured and site-constructed assemblies. *Clockwise from lower left:* Adam Jordan, Shelton Weatherford, and Jasem Pirani.

Easily erected. She had shaped the unit so that three collapsed units could fit on a single flatbed trailer. Because of fiberglass’s strength relative to its lightness, Irons proposed that a single unit could be erected on site with a simple forklift and three able-bodied volunteers or relief workers. Helkamp’s prefabricated house would be erected by the manufacturing company. He assumed that the erection crew would be trained and so the building assemblage sequence could use heavier equipment and could be more complicated than Irons’ proposal.

For most comprehensive studio projects, students may address the larger issues of systems integration but cannot address building detailing and construction tolerances. Issues of how modules assembled, how the house would attach to the foundation, and how tolerances were detailed between factory-made and site-constructed elements would become critical in the prefabricated house studio. See Figure 5. Returning to Jordan’s prefabricated unit constructed of dismantled airplane components, he had proposed that his units would be deployed as campsites throughout the Pacific Northwest and would be independent of any city services. As part of his proposal, the entire prefabricated unit would be trucked to the site and erected as needed. Jordan was concerned about how the precise curve of his airplane panels would meet the foundation supports. He proposed that a precast foundation matching the curve of the airplane would be constructed to be used at the building foundation, offering a more precise fit than a site cast foundation. Shelton Weatherford chose to address a housing need in the Mississippi Delta region of the United States. Users of her prefabricated unit would include seasonal migrant workers, musicians, and students. It was intended that her users would occupy their residences for only three-fourths of the year, and so a low-tech system of venting, heating, and plumbing would be required. Weatherford’s units were constructed of singular modules that could fit on a flat-bed truck to be transported to the site. Her consumer profiles also necessitated a low-tech foundation system that could be erected by the consumer themselves. Weatherford proposed using a simple precast concrete foundation pier—often used for exterior decks—that can be purchased at any home improvement store. She designed the piers eight feet on center so that they would be smaller and easily hand dug. A simple tube water level could be used to ensure that the top of the piers were level with one another. As part of Jasem Pirani’s design, he proposed installing his units on existing low-slope roof tops in the dense urban
areas of the Northeastern corridor. He sought a lightweight structure that would not place too much dead load on the roof deck and a structure that could adjust to a possible changing slope. To this end, Pirani proposed assembling three smaller modules with a flexible joint between them. This flexibility allowed the modules to be leveled individually and the joint responded to the potential unevenness between the modules.

Conclusion

I believe that the small sampling of projects within this paper illustrates the variety of approaches and issues that students addressed through this comprehensive studio. Traditionally, the comprehensive studio is a design project that is modeled on the professional design process and is required to address a number of performance criteria. Some of the required criteria may change from program to program, while many remain universal across most comprehensive studios. Because the required criteria are so numerous, fulfilling all of the criteria becomes the studio’s focus and building design suffers. While this studio mirrors a typical experience in the profession, it does not offer the student a chance to explore systems integration as design nor to propose alternative systems. By contrast, in the comprehensive studio that I developed, I utilized the design problem of prefabricated housing.

By giving the design problem of a prefabricated house, it reduced the size of the design problem but not the scale of the project’s complexity. Benefits of and skills learned through this studio included: exploring innovative materials and building assemblage processes; understanding building systems through designing the building core; and addressing the design interface between site building and factory-manufactured building tolerances. These benefits moved the studio beyond the required performance criteria and gave the students a more dynamic way of understanding the potential of design. The prefabrication studio also gave students the opportunity to consider new ways of approaching design, breaking the traditional mold of first designing the building and then adding traditional systems to that design. I believe that because of the new materials that students explored, innovative applications of building systems, and new understandings of building assemblages, that these students will be better positioned to propose new possibilities of architecture technology. Because of this studio, students may challenge the traditional design of building systems, structure, assemblage, and materials and may work with consultants to develop new approaches of building design.

Notes


2 Although NAAB does not require a comprehensive studio, they do specify Comprehensive Design as one of their student performance criteria. NAAB defines the Comprehensive Design criteria as the “Ability to produce a comprehensive architectural project based on a building program and site that includes development of programmed spaces demonstrating an understanding of structural and environmental systems, building envelope systems, life-safety provisions, wall sections and building assemblages and the principles of sustainability.” (NAAB Conditions for Accreditation, 2004 Edition). Most comprehensive studios require this criterion as part of student assessment, however the criteria for the studio is often not limited to this one criterion.

3 Information has been informally obtained through investigation of selected syllabi from schools that offer comprehensive studios. Schools included are Savannah College of Art and Design, University of Kentucky, University of New Mexico, and Catholic University of America.