Learning Through Lightness

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ABSTRACT: This paper documents the methods and results of a one-semester design-build seminar that synthesized sensor technology, computational design, digital fabrication methods, and construction practices in the design and construction of a light-weight interactive installation. Asking the question "how can the concept of lightness serve as a pedagogical tool for framing small-scale design-build projects?" students in this course wrote custom software for evaluating the thermal performance of lightweight material choices. The result is a novel and disassemblable accessory dwelling unit (ADU) prototype that eliminates active systems and reduces material excess through digital intelligence. An overview of Buckminster Fuller's early work on geodesic structures with students at Black Mountain College in the summers of 1948 and 1949 serve to ground the research and frame lightness as a framework for teaching students the complexities of construction through experiential learning within an academic context.

KEYWORDS: Design Pedagogy, Design-Build, Digital Fabrication, Computational Design, Interactive Architecture

INTRODUCTION
This paper explores the concept of lightness as a pedagogical framework for realizing short-term design-build projects with students of architecture. At its core, the investigation advocates for the design-build model as an impactful method for distilling the complexities of building through a curriculum that draws upon John Dewey's experiential approach to education.[1] Two factors, however, make teaching design-build studios a challenge: 1) the lengthy process of building due to the time intensive process of construction itself, and 2) the growing complexity of construction today due to the involvement of multiple trades and the need to integrate an increasing number of building technologies. These conditions make it difficult for architecture students to holistically experience and understand the act of building within the contexts and constraints of architecture education.

As a solution to this situation, this paper proposes using the concept of lightness as a framework for adapting the complexities of building to the contexts of architecture schools and, in turn, leverage the design-build model as an opportunity for experimentation and innovation. As a point of reference, this investigation looks to Buckminster Fuller's early work on geodesic domes and his first teaching assignment at Black Mountain College from 1948-1949 to learn how small-scale design-build projects premised on lightweight construction can provide a meaningful and heuristic educational experience in building design.

1. CONTEXT
This paper asks the question: "how can the concept of lightness serve as a pedagogical tool for framing small-scale design-build projects?" As a grounding reference for the research, this investigation looks to Buckminster Fuller's work on geodesics and the method in which he translated his early conceptual models into inhabitable forms alongside students at Black Mountain College. Founded in 1933 in western North Carolina, the institution became a testing ground for pedagogical innovation in the arts under the leadership of Josef and Anni Albers and others until its closing in 1955. As the inaugural visual arts program leader, Josef Albers brought an emphasis on experimentation and an experiential approach to arts education that were derived from his own familiarity with John Dewey's philosophy of "learning by doing" and his experience as the instructor of the Preliminary Course (Vorkurs) at the Bauhaus prior to his arrival at Black Mountain.[2]

It was within this culture of testing and creative innovation that Buckminster Fuller arrived for his first teaching assignment in 1948. Josef and Anni Albers, John Cage, Merce Cunningham, Willem de Kooning and Fuller formed a core faculty that were joined by approximately seventy-five students at the College's 1948 summer session. Fuller at the time was developing his own research on lightweight forms of construction, an idea that was represented by his aluminum and steel Great Circle Sphere Model—a network of overlapping flat circular members that distributed forces along the exterior without need for interior bracing.[3] It was at Black Mountain where Fuller's nascent geodesic design principles intersected with the College's exploratory culture to convert his conceptual models into occupiable forms. This translation was made possible through a novel pedagogical vision developed in collaboration with John Cage and Merce Cunningham. In an interview with Mary Emma Harris, Fuller recalled how, "John Cage and Merce and I had breakfasts every morning out under the trees" during which time they developed the concept of their "finishing school," where they would "finish anything" and "really break down all of the conventional ways of approaching school."[4]

It was with this attitude towards execution in which Fuller worked with students to erect the first attempt at a geodesic dome. While the subsequently named "Supine Dome" failed to rise due to the damp morning conditions and the insufficient strength of the commercial venetian-blind slats used for its construction, the process proved to be a valuable learning experience.[5] Despite Fuller being aware that the slats lacked the strength to support the structure, he pushed on in an effort to see the project through with the students and advance his philosophy of lightness by demonstrating buildings could be constructed incrementally with lightweight materials.[6] While the efforts of that summer proved to be unsuccessful, Fuller's ability to simplify the act of building into a tangible and experiential process framed the exercise not as failure, but as a first step in a larger design project. The lessons learned from the Supine Dome were on full display the following summer when Fuller returned—this time as the summer session organizer with the resignation of Theodore Dreier and Josef Albers—and realized a free-standing version of the dome, this time using linear elements and connecting nodes.

Fuller's teaching at Black Mountain holds resonance today in an era where the process of building is an ever increasingly complex process. By taking cue from Fuller's focus on small-scale lightweight structures, we can learn to frame the design-build model not as a one-off exercise, but rather as a collective series of experiments towards a long-term strategy for design.

2. METHODOLOGY

The Color of Air is an installation that explores the pedagogical potential of small-scale lightweight design-build projects to holistically understand and analyze the process of building. The project was designed, fabricated, and constructed with undergraduate and graduate students through a one-semester seminar course at the University of Tennessee College of Architecture + Design. The installation synthesized sensor technology, computational design, digital fabrication methods, and construction practices in the design and construction of an accessory dwelling unit (ADU) prototype that offset material excess with digital intelligence. As a pedagogical exercise, the design-build project introduced students to the process of building through an experiential approach to construction.

The installation is an 84 square-foot tea house designed to eliminate the need for active systems through lightweight materials and the integration of sensor technology. (4) air inlets at the corners of the floor and door and (2) along the roof ridge induce natural ventilation flows within the space through a stack-effect. Movable furniture and the doorway located at the corners create a system for modulating airflow through the interior. The project incorporates temperature, humidity, and airflow data collected from sensors to design a dynamic facade system that allows visitors to understand both interior and exterior thermal conditions through their physical interactions with the structure (Figure 1). Through its small scale, legible constructability, and interactive interface, the installation proposes a lightweight dwelling prototype that can communicate and respond to local contexts and conditions.

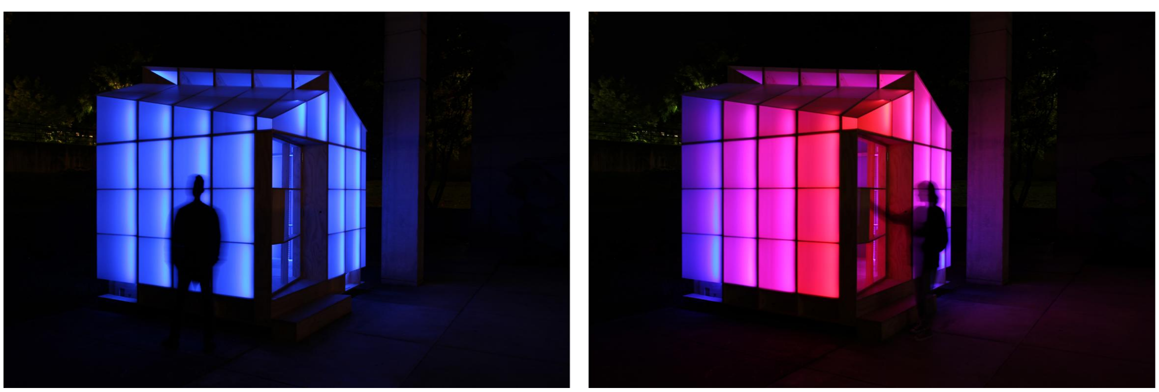

Figure 1: The project supplants active systems and material excess with digital intelligence—red and blue hues convey warmer and cooler interior temperatures respectively. Source: Authors

2.1 Lightness as a model for integration

At a pedagogical level, lightness served as a framework for distilling the complexity of building down to core concepts that could be explored in a single project. Drawing upon Fuller's concept of a "finishing school," the installation was envisioned as a one-semester exercise in which students could experience the design, development, construction, and evaluation of a building from beginning to end. Conceptually, this approach impacted the installation's design in two ways: 1) the project's physical size, and 2) the elimination of active building systems and the excessive use of materials.

The solution was to frame the installation as a heuristic device and feedback loop for understanding the thermodynamic principle hot air rises. By communicating the structure's thermal conditions through an interactive facade system, the need for active systems or excessive materials could be supplanted by users' own experiential understanding of the project and the way it performs.

As a result, The Color of Air necessitated integrating sensor technology, computational design, digital fabrication, and construction practices to collect data, operate its interactive facade system, create lightweight and customizable members, and provide structural stability where necessary. Perhaps the most compelling representation of this integrative approach was the project's construction documentation that expanded upon the conventional drawing set to include CNC cut files, Arduino C++ scripts for reading sensor data and controlling the addressable LED lights, and JavaScript code for parsing local weather data to be used in comparison with internal temperature and humidity data readings (Figure 2).

By committing to a concept of lightness, the project was able to remain at a small scale and free from active systems and the use of excessive materials, which in turn allowed for a level of experimentation evocative of Black Mountain College's culture and attitude towards arts education.

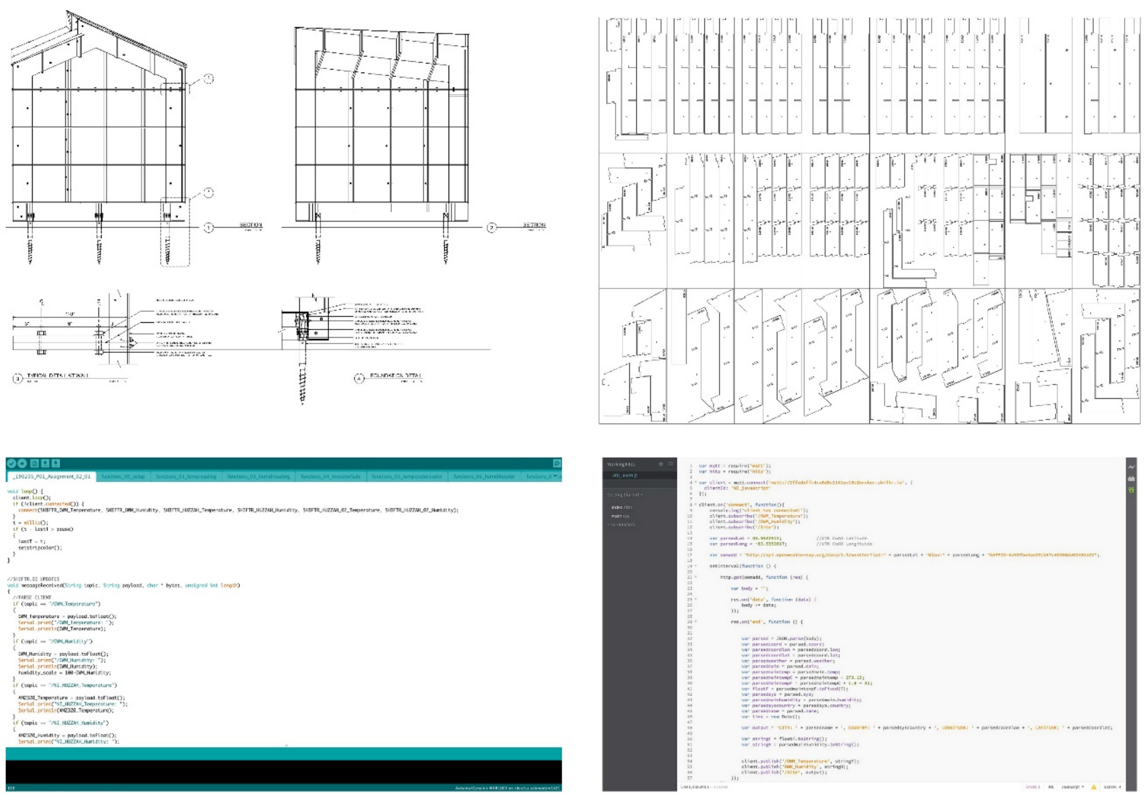

Figure 2: Clockwise from top left: sheets from the drawing set, CNC mill files for fabrication, JavaScript code for parsing local weather data, and an Arduino C++ script used for reading the sensors and controlling the addressable LED lights. Source: Authors

2.2 Designing for disassembly

Lightness as a concept for construction served the project in two ways: 1) the process of building and re-building the installation operated pedagogically to reinforce the students' understanding of how the project was designed and constructed, and 2) the project's ability to be disassembled allowed students to test the installation's performance in two different site contexts.

Three significant choices were made regarding the project's materiality. The first was the use of 3/4" radiata plywood for the walls' and roofs' primary structure. The customized design of these elements necessitated the use of the CNC mill and in turn a plywood material that could both be cut and provide structural rigidity. 3/4" was determined to be an appropriate thickness and radiata was selected for its clean appearance and relatively inexpensive cost. The second choice was the use of clear corrugated polypropylene for the exterior cladding. This material was selected for its translucent appearance that would permit the interior to be naturally lit during the day and allow for the LED lights to illuminate the exterior at night. The third choice was the use of American Ground Screw U-Model ground screws as a foundation for the structure. This foundational system was selected to provide a temporary foundation as the project was designed to be transported and eliminate the need for the energy intensive use of concrete. Originally designed for mailboxes and exterior decks, the installation's size provided an opportunity to test this foundation system for small-scale dwelling structures.

The installation was designed with the two constraints in mind: 1) the project must be buildable by the author and students without the use of a crane, and 2) the installation must be disassemblable and fit within a U-Haul truck for transportation. To be both lightweight and structurally sound, a hybrid construction method was employed for the installation (Figure 3). CNC milled plywood was used for the wall and roof structure and a conventional wood framed floor was used to support the building. For the installation to be disassemblable, the walls and roof were designed as modular bays approximately two feet wide and connected with thru bolts. The overall structure was designed to be transported in a single 26-foot-long U-Haul truck (Figures 4). As a prototype for ADU construction, the project is designed to be transported through a side yard and erected by a team of two or three individuals without the use of a crane.

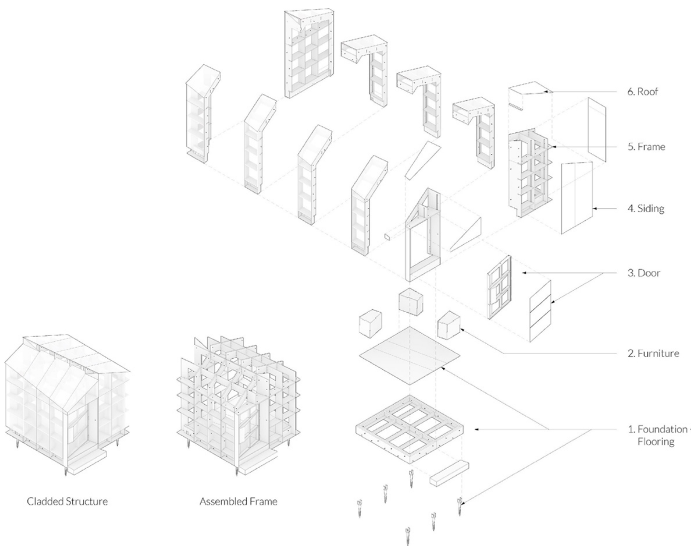

Figure 3: A hybrid construction system that combined traditional wood framing with digital fabrication methods was used for the project. Source: Authors

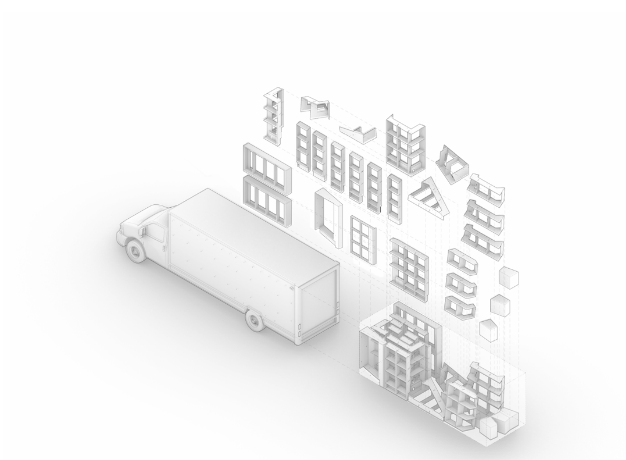

Figure 4: The installation was designed to fit within a single 26-foot-long U-Haul truck. Source: Authors; and photograph of the installation loaded for transportation. Source: Authors

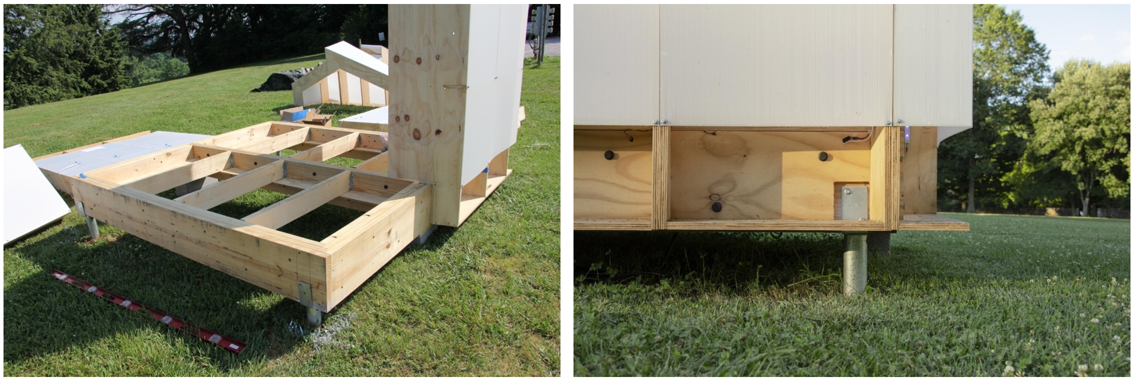

Figure 5: The first phase of construction is the marking and installation of the temporary ground screw system. Source: Authors; and The ground screws provide a lightweight and ecological alternative to conventional concrete footings. Source: Authors

The phasing of the installation's construction is a three-part process. The first is the marking and installation of the ground screw foundation system (Figures 5). Next is the setting of the wood framed floor. Lastly is the erection and bolting of the plywood walls and roof. The structure's modular design allows for it to be constructed in a single day (Figure 6). Through its operable ventilation system and translucent skin, occupants can modulate the building's thermal performance and engage with the environmental conditions of the local area (Figures 7).

Figure 6: The integration of digital fabrication methods and construction practices enable the structure to be built in a single day. Source: Authors

Figure 7: Occupants can modulate the structure's thermal performance through operable doors and openings. Source: Authors; and tthe installation's translucent and lightweight skin allows occupants to engage with the environmental conditions of the site context. Source: Authors

3. RESULTS

From a pedagogical standpoint, the project had two significant outcomes. The first was the installation's small size, elimination of active systems, and restrained use of materials enabled students to execute the installation in a single semester. Furthermore, the limited scope of the project allowed them to take an active role in the design, development, construction, and evaluation of the building from beginning to end. As a result, students were actively engaged throughout the project, and they had a thorough understanding of the installation's design and how it performed.

A second outcome was the installation's ability to be disassembled enabled students to rebuild it on two different sites. The process of constructing the structure multiple times reinforced their understanding of the structure and framed the act of building not as a one-off exercise, but instead a series of experiences that could be applied in different situations and conditions. Being able to study the structure in two different locations additionally demonstrated the impact varying site conditions can have on a building's performance.

From a construction standpoint, the project demonstrated how temporary foundation systems can provide novel solutions for small-scale dwellings. The ground screws' capacity to support structures of this size show they can serve as an effective alternative to the energy intensive use of concrete. Furthermore, their ease of installation and relatively small size make them a viable solution for temporary structures that must minimize their impact on the site and soil.

CONCLUSION

By leveraging lightness as a framework for design-build studios, we can distill the complexity of building down to foundational concepts for students of architecture. Drawing upon the lessons of Buckminster Fuller and his interactions with students at Black Mountain College, a lightweight approach to building positions the act of construction not as isolated incidents, but rather steps within a larger design process. By keeping the scope small, educators can frame the design-build format and the process of design, development, construction, and evaluation as an iterative and recursive model for disciplinary experimentation and innovation moving forward.

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ENDNOTES

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