The Color of Air: Integrating Code with Design-Build Education

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INTRODUCTION

The Color of Air is an installation that integrates code with design-build education to introduce students to the process of computer programming and to evaluate building performance. The project incorporates code, digital fabrication methods, and construction practices to create an interactive space that teaches students fundamental thermodynamic principles by way of their interactions with the structure. Through a project-based curriculum that adopts John Dewey's experiential approach to education, the installation empowers students with tools and experiences for understanding, applying, and evaluating the impact of their designs within the built environment.

BACKGROUND

The growing effort by contemporary design educators to represent the act of building as a holistic process is exemplified by Kiel Moe's call for "integrated design" and Tricia Stuth's "designbuild-and-evaluate" approach.[1] Code offers a way of thinking to stitch the distributed processes that constitute building into a synthetic whole, as reflected by Casey Reas who uses the term "procedural literacy" to frame programming as an "act of communication and a symbolic way of representing the world."[2] While software skills are increasingly valuable for next generation architecture students, Reas acknowledges "integrating them into design education is a challenge," due to software's technical demands and abstract nature.[3] By pairing coding with building, students can form what Kiel Moe and Ryan Smith identify as "feedback loops" to make tangible and understand the language, syntax, and logic that structure software development.[4]

Drawing upon American educator and philosopher John Dewey's "experience" centered educational approach for realizing and developing students' inherent "impulses" to learn, this installation was realized through a one-semester seminar course that took a project-based approach.[5] By acknowledging the role "action plays in the development of intelligence," and re-establishing the "organic connection between education and personal experience," the class leveraged building to teach concepts in coding and coding to evaluate building performance.[6]

PROJECT AND METHODOLOGY

The Color of Air is an interactive 84 square-foot tea house for studying the thermodynamic principle hot air rises. (4) air inlets at the corners of the floor and door and (1) outlet along the roof ridge induce natural ventilation flows through a stack-effect (Figure 1). Distributed sensors record changes in temperature, wind speed, and humidity, and movable furniture and an operable doorway create a system for modulating airflow through the interior. By observing changes in the project's dynamic lighting system and re-arranging the furniture and doorway, occupants can modulate their thermal comfort through their interactions with the space (Figure 2).

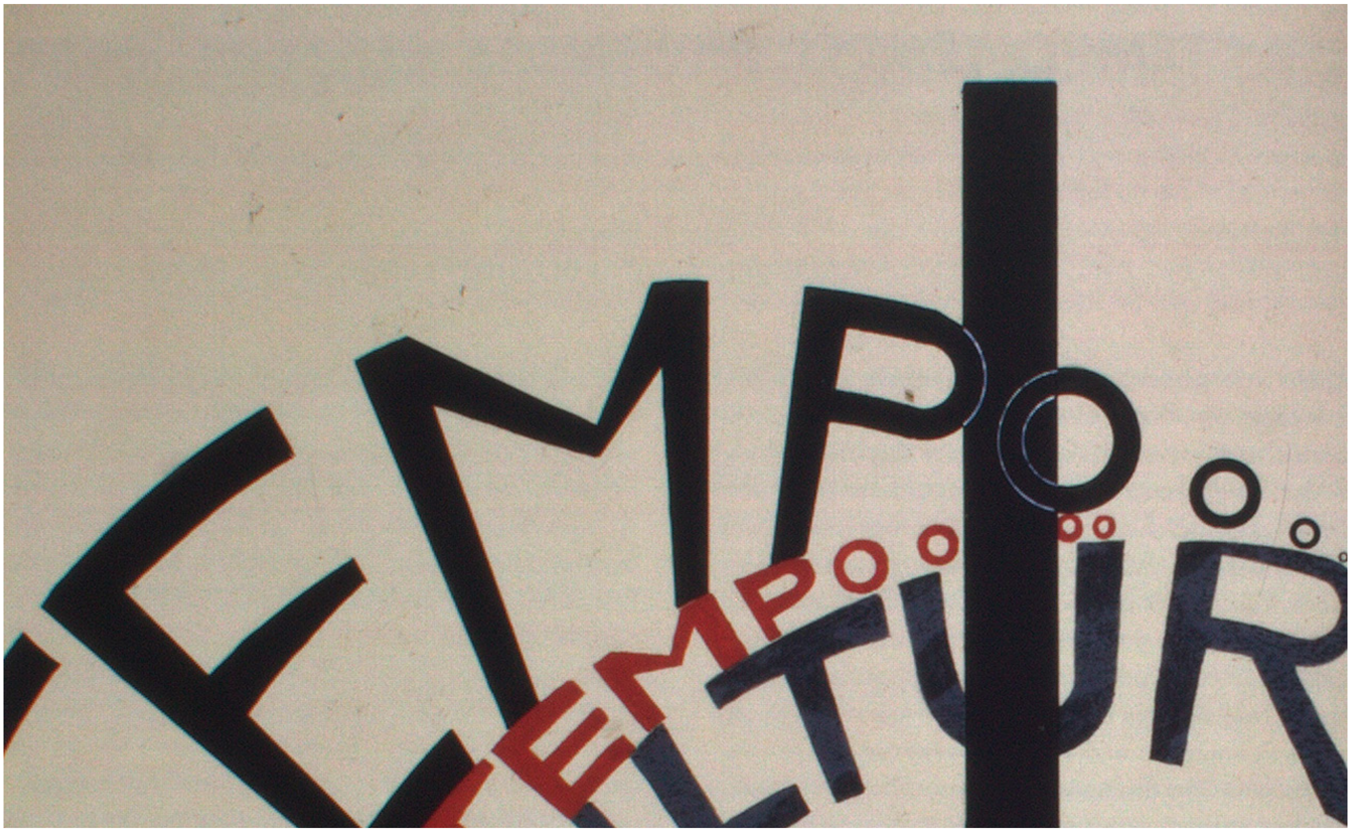
To represent real-time thermal conditions, the class developed custom software to control addressable LED lights for communicating changes in temperature, wind speed, and humidity. The process of translating thermal sensor data is a three-part process: 1) Wi-Fi-enabled microcontrollers connected to sensors monitor temperature, wind speed, and humidity conditions while a JavaScript code parses local weather information from OpenWeatherMap to provide a reference temperature for comparison, 2) an MQ Telemetry Transport (MQTT) platform shares the parsed data with Wi-Fi enabled Arduinos connected to addressable LED lights, and 3) the Arduino microcontrollers operate the LED lights to communicate the data through changes in hue, saturation, and brightness (Figure 3, 4).

DESIGN PEDAGOGY

The installation was realized through a one-semester seminar course that was composed of six undergraduate and five graduate students from the University of Tennessee. The class was structured through two concurrent projects to provide the students the opportunity to work collaboratively on a single project and individually to develop a working knowledge of the software behind the installation.

PROJECT 01: THERMAL SCREEN

The first project focused on developing students' technical skills and introduced them to the concept of procedural literacy through the framework of physical computing. The code that was used in the final design-build installation was introduced on day one.



Opening Figure. *The Color of Air* integrates code with design-build education to introduce students to the process of computer programming and to evaluate building performance.

This project was divided into two phases. In the first phase students worked individually with a single microcontroller, sensor, and LED diode to design a 1:1 scale lamp that shifted in hue and brightness in response to changes in temperature and humidity. By manipulating the code to change the lamp's hue and sensitivity, students were able to understand the code's language, syntax, and logic as well as make thermodynamic distinctions between hot and cold and wet and dry at a small scale.

In the second phase students worked in groups to combine computer programming with digital fabrication techniques to design and build a 1:1 scale thermally responsive facade system. Students produced drawings of their assemblies that documented the integration of microcontrollers and sensors with their digitally fabricated designs and diagramed how their systems performed thermally. By designing and fabricating a system that involved multiple sensors and a linear strand of addressable LED lights, students applied their understanding of the project's code at a larger scale.

PROJECT 02: THE COLOR OF AIR

Concurrent with Project 01, students worked on the design, development, fabrication, and construction of the 1:1 scale tea house. Students were subdivided into four teams—material research, digital fabrication, lighting design, and computer coding—that worked to execute the project collaboratively.

The structure's modular design draws upon lessons learned from Project 01 and allows for it to be constructed in a single day (Figure 5, 6). The integration of the custom software developed by the team allowed students to not only understand the working logics behind the project, but also evaluate the structure's performance through its interface and their interactions with its operable components.

CONCLUSION

Incorporating code with the design-build process not only provides students with a framework to develop procedural literacy and computer programming skills, but also a method for understanding and evaluating how buildings perform. This project has two observed learning outcomes: 1) it allows students to understand their work in quantitative and qualitative terms, and 2) it provides them a method to test design hypotheses and analyze results through the creation of interactive feedback loops.

This project creates a pedagogical scaffold for students to understand, apply, and evaluate the impact of their design decisions through the incorporation of Dewey's experiential approach to learning. By equipping them with a set of tools, experiences, and higher order thinking skills, we can empower our students to create new methods of making and building responsive to the growing complexity of the profession and discipline today.

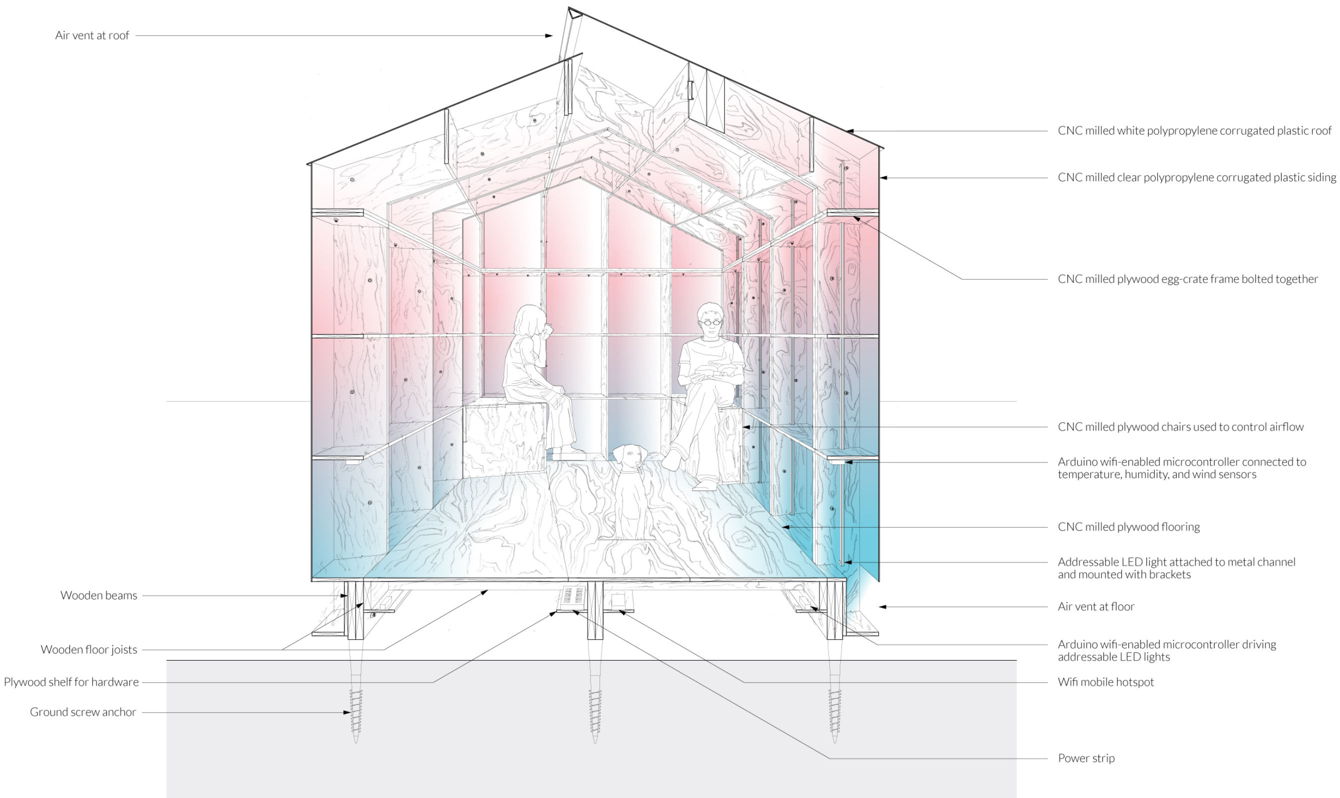


Figure 1. Openings at the floor and along the roof ridge induce natural ventilation through the space.

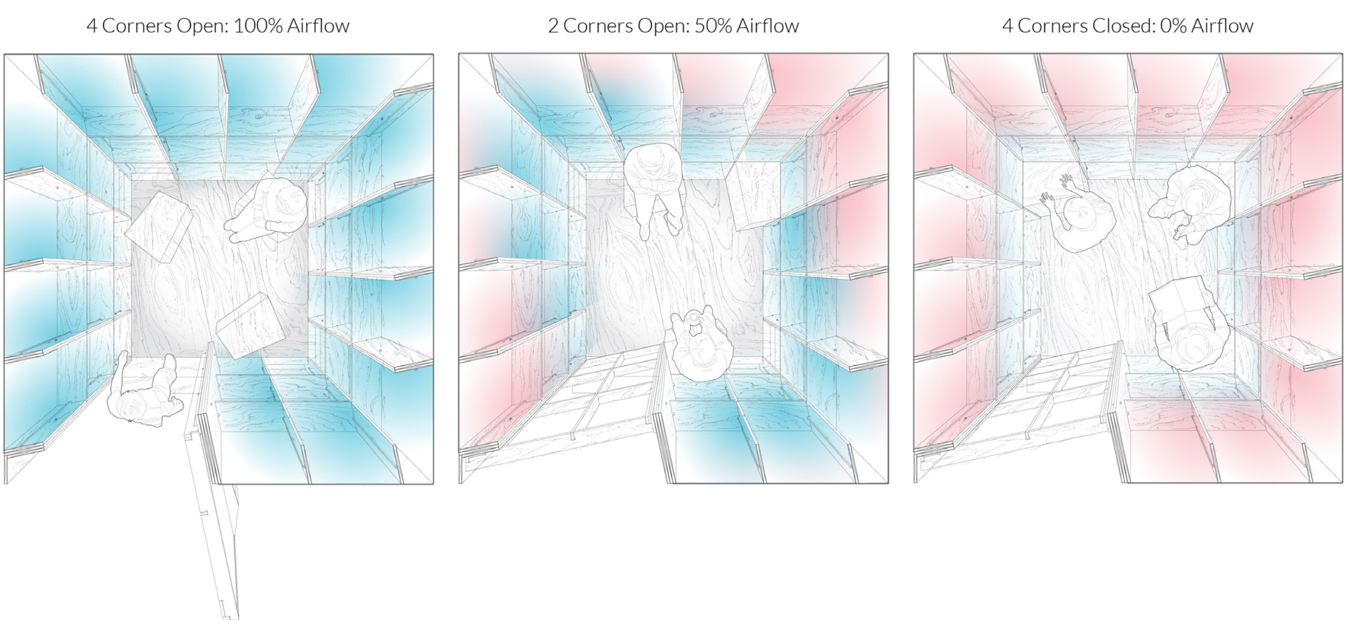


Figure 2. Occupants can modulate their thermal comfort through their interactions with the space.

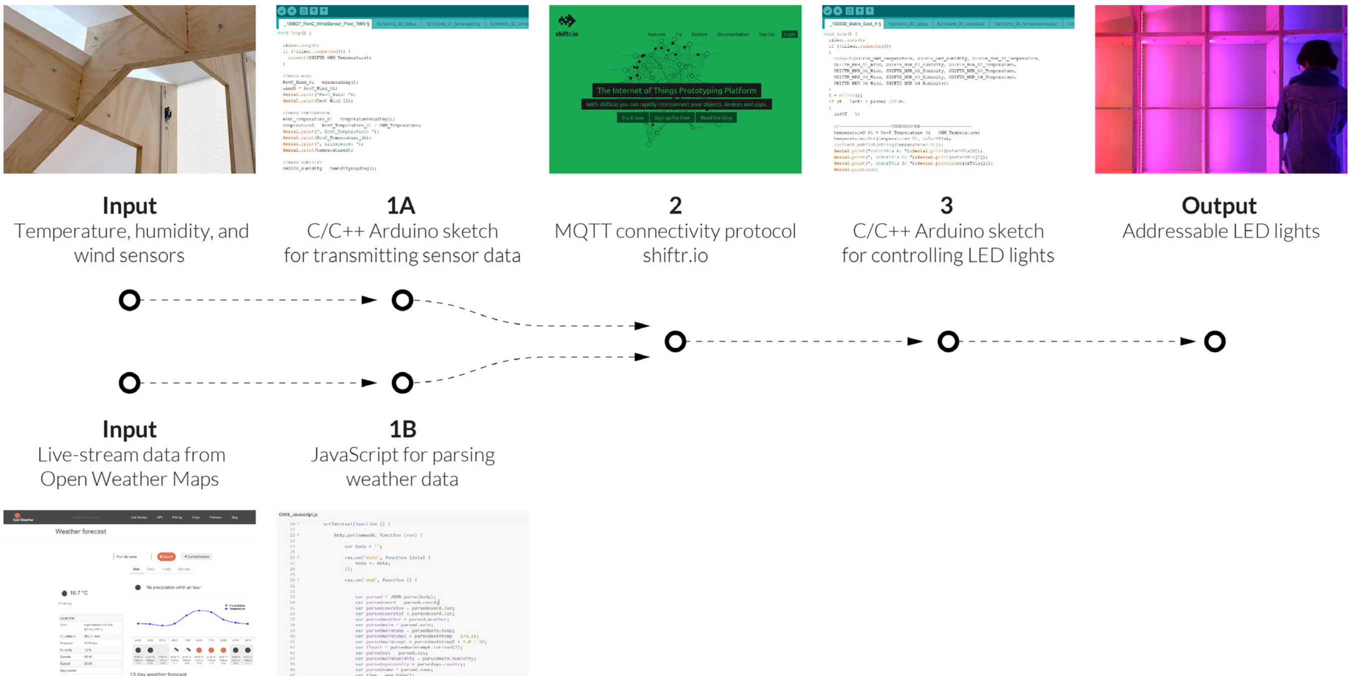


Figure 3. Sensor data collected at the ventilation openings is measured in relation to local weather data and translated into lights through a three-step process.

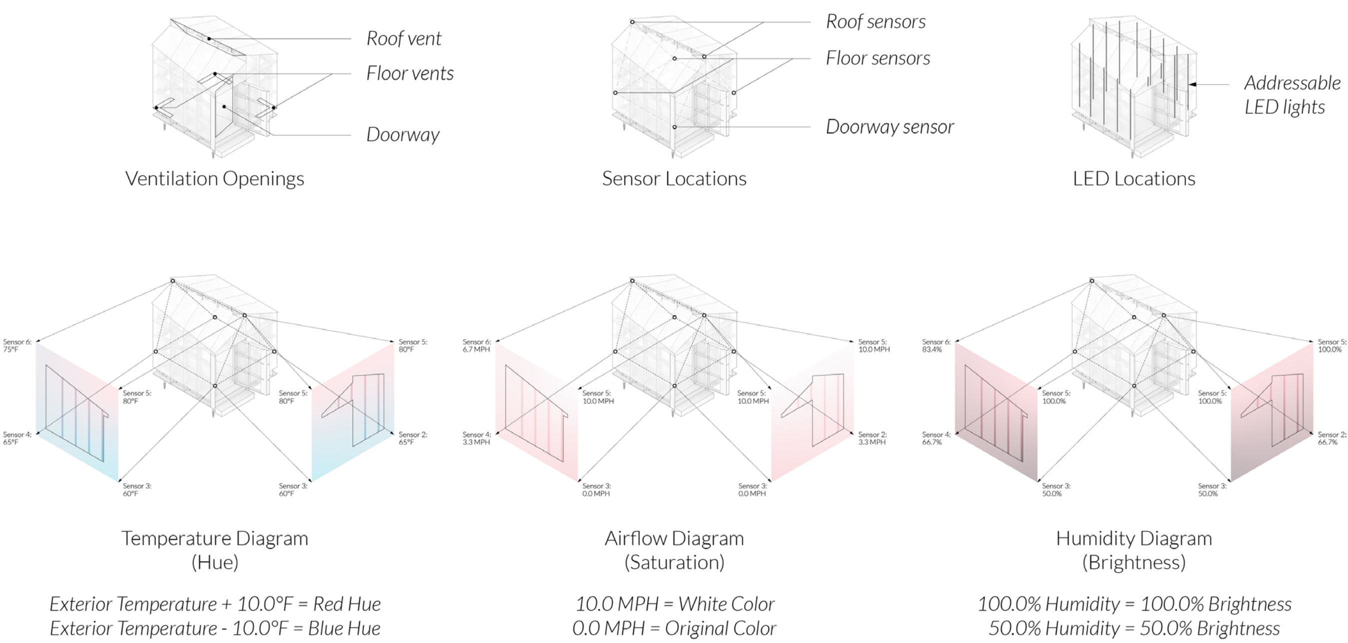


Figure 4. Differences in temperature, wind speed, and humidity are registered as shifts in the lights' hue, saturation, and brightness, respectively.

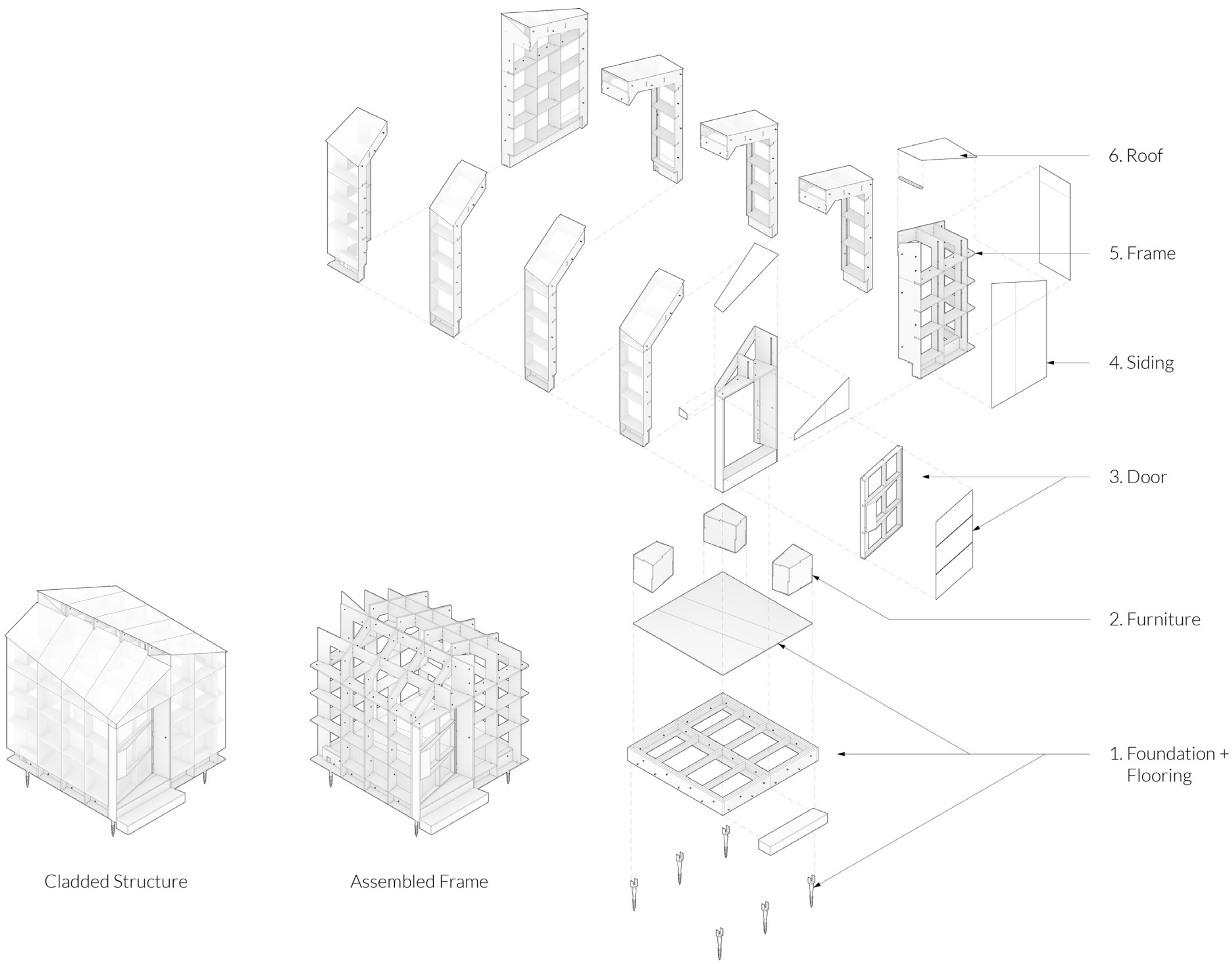


Figure 5. The project combines traditional wood framing and digital fabrication methods to develop a construction system that is modular and designed for disassembly.

Figure 6. The process of disassembling and reassembling the structure for installation reinforced students' conceptual understanding of the project's fabrication and construction logics.

Closing Figure. By equipping students with a set of tools, experiences, and higher order thinking skills, they can be empowered to create new methods of making and building responsive to the growing complexity of the profession and discipline today.

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ENDNOTES

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6. John Dewey and Evelyn Dewey, "Democracy and Education" in *Schools of Tomorrow*, by John Dewey and Evelyn Dewey (New York: E. P. Dutton & Company, 1915), 305; Dewey, *Experience and Education*, 25.