Teaching carbon responsibility to first year architecture and engineering design students

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ABSTRACT: *In architecture and engineering schools in the US, environmentally responsible building technologies are often taught in upper division curricula. This paper argues that environmental ethics and responsible material use should be foundational to architecture and engineering design education. The authors discuss a pedagogical framework developed for Cal Poly San Luis Obispo first year architecture and architectural engineering students for introducing carbon responsibility through an ethic of wood use where wood is locally sourced and kept in use through buildings and furniture products. Over the course of a term, students engaged with the full arc of the life cycle and use of wood in buildings. This involved planting trees, watching a milling demonstration using local urban wood, and designing an all-wood speculative project. The term culminated in the design and fabrication of a functional full-scale wood object, made of donated urban wood, which students constructed with minimal or no glue. Using local wood rather than Home Depot lumber for the 240-person studio saved over 1,000 kilograms (1.1 tons) of carbon dioxide emissions from transport.*

KEYWORDS: Foundation Design Pedagogy, Wood Structures, Carbon Sequestration, Urban Wood, Circularity

INTRODUCTION

This paper argues for an alternative pedagogical framework for foundation level architecture and engineering design students where material and ethical constraints guide learning objectives. Often in architecture and engineering curricula, building technology (and therefore environmental) concerns are introduced in upper division “support” courses such as Environmental Controls and Materials and Methods. In these scenarios, some first-year design studios abandon real-world constraints to allow formal freedom and design exploration. In contrast, the authors argue that teaching environmental and material constraints should be foundational. For this reason, they developed a core curriculum for first year architecture and engineering students in which assignments were driven by environmental ethics and material responsibility through a focus on wood. By constraining the material to wood and all-wood assemblies, the authors argue, students gained design sensibilities in parallel with an environmental ethic as a core principle of designing buildings today. The design studio’s focus on wood proves straightforward. Afforestation, reforestation, and forest stewardship are critical components of climate change mitigation and adaptation. (Griscom et. al. 2017, USGCRP 2019) Trees sequester carbon, but decomposing trees or chipping them releases carbon back into the atmosphere. When sustainably harvested, the best end-of-life use of trees are wood products including buildings and furniture, which enable continued carbon storage. (Sather and O’Connor 2010, MIT Climate Portal 2022) Given the urgency to address climate change caused by the built environment (GlobalABC 2021), the authors developed a curriculum to instill an ethic of wood use and stewardship. Through activities and projects, the curriculum aimed to teach students about the life cycle and benefits of using wood in building and structural design.

To push the agenda further, the design course emphasized the importance of *specifying local wood*. In *Wood Urbanism*, Jane Hutton describes that plantations provide one third of the world’s wood and that these plantations are often monocultures planted for maximum harvest and financial return. (Hutton 2020) Hutton goes on to explain the negative impacts of plantations, which are often planted where biodiverse forests once stood and provided livelihood and sustenance for indigenous and local peoples. The clearcutting practices used by plantation owners contributes to “land degradation, erosion, water pollution due to applied chemical fertilizer and pesticides, and drought.” (Hutton 2020) These practices have negatively transformed US forests. A University of Michigan study found that since 1600, 90% of the virgin forests have been cleared, despite that extensive clearcutting began only 50 years ago. (Buis 2019 and *ResEarth*) As a result, the pedagogical agenda described below sought to engender a deeper understanding about wood and where wood products come from. Through fruitful partnerships both on and off campus, the course provided learn-by-doing experiences involving planting trees locally and using local wood.

1. PURPOSE

The fall quarter of the first-year design curriculum focuses largely on abstract, compositional ideas. Previous iterations of the winter quarter curriculum sometimes became an extension of the fall quarter where assignments focused on formal output alongside digital and analog representation and skill-building. One consequence of this curriculum is that it often generates a lot of non-recyclable and non-reusable waste. The 240 first-year students make significant contributions to the 7,000-pound dumpster container that awaits refuse at the end of each quarter. Recognizing the local and global real-world problem of curricular and building industry waste, the authors sought to develop a curriculum where the materials were recyclable or biodegradable, or even better, kept forever.

Driven by the need for waste reduction and carbon sequestration, the design course focused on an ethic of wood use as a multi-pronged objective where wood is locally sourced from a variety of species, wood is used in the design of buildings and furniture as much as possible, and wood is kept in use rather than discarded in a landfill. Over the course of the term, students engaged with the full arc of the life cycle and use of wood in buildings. The “wood studio” involved planting trees on campus, watching a milling demonstration using local urban wood, designing an all-wood speculative project, and designing and fabricating a functional full-scale wood object made of donated urban wood, which students constructed with minimal or no glue.

2. PEDAGOGICAL METHODS

The focus on environmental ethics and responsible material selection for the wood studio marks a significant shift from the pedagogical framework and abstract assignments that dominated the studio content in previous years. Whereas the primary learning objectives had been geared towards representation, beginning design, and skill-building, the learning objectives for the wood studio upheld the benefits of wood use and understanding wood sourcing and assemblies as the primary goals. Analog and digital skill building, and representation techniques were embedded in the course assignments, but were not the end in themselves. To demonstrate the shift in learning objectives, three previous assignments are compared to three of the main wood studio assignments: a precedent study, a speculative design project, and a woodshop demonstration project.

In previous years, the precedent assignments in the first-year studios have focused on small projects, such as houses or pavilions, with the primary goal of teaching the process of studying and explaining precedents in preparation for a design project. Previous deliverables included asking students to create slide presentations, printed boards, diagrams, and/or digital models of the buildings. For the wood studio, the focus centered on learning about wood structures, representing a more technical and tectonic approach. Students worked in pairs to investigate and understand wood projects and described these to the class through a verbal presentation and slides. Presentation content included a brief description of the architects and engineers, and information (as much as could be found) about the design process, construction, and wood material.

Students then worked individually to model a tectonic chunk of the wood project in McNeal’s Rhinoceros (Rhino). The purpose of digitally modeling a tectonic chunk was to learn about floor, ceiling, and wall wood assemblies including the hierarchy of structure and cladding. On a basic level, students gained an understanding of the relative sizes of wood members for different structural or cladding purposes. A secondary benefit of the modeling exercise was to further the students’ Rhino 3d modeling skills since they had only used Rhino in 2d in the previous term. The final output requested two side-by-side isometric views of the tectonic chunk. Well-executed examples demonstrate an understanding of wood systems including wall and floor or ceiling systems. (Figure 1) Students based the tectonic chunk model on 2d drawings imported into Rhino, which were then traced and modeled through extrusion and other techniques. When high resolution or detailed dimensions were not available, students worked with faculty to take their best guess based on typical lumber dimensions.

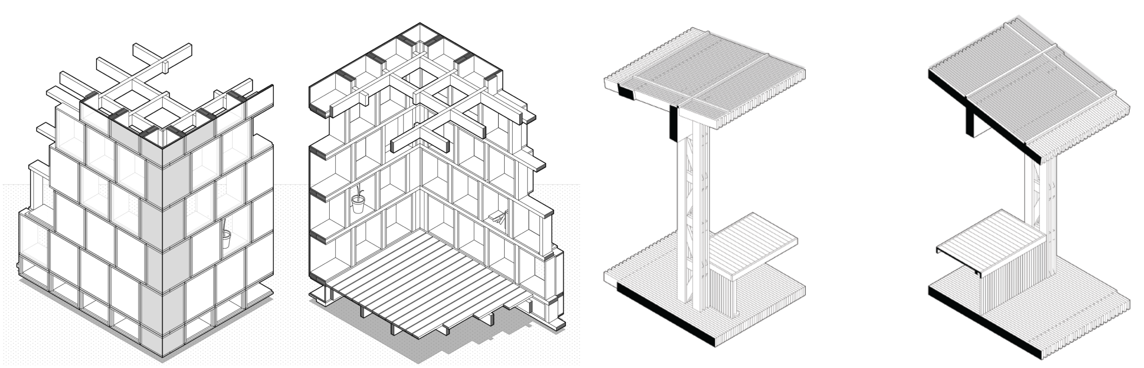


Figure 1: First Year students, Benoit Lepottier and Kelsey Howryla’s isometric drawings of a tectonic chunk of CLP Architectes’ Observatory Pavilion in Muttersholtz, France and Bornstein Lyckefors Arkitekter’s Kärdla City Pavilion in Estonia. Sources: (Benoit Lepottier and Kelsey Howryla 2022)

Building on knowledge gained from the wood precedent assignment, the speculative design project assigned for the wood studio also marked a shift from previous speculative design projects assigned in first year. The basswood modeling project of years past had similar learning objectives including to “understand simple structural relationships” of the building site, which was a wood pier. For that assignment, students had worked in groups to analyze the existing structure alongside other environmental and historical data. They continued the group work to create speculative designs for wood structures sited on top of the pier; however, the wood materiality of the projects was permitted to play second seed to formal ambitions. In contrast, for the wood studio, each student developed a design for a 1,000 square-foot all-wood, open-air pavilion housing an arborist’s office and a presentation space sited in the campus arboretum. The arboretum site allowed for a discussion about the wood structure relative to the surrounding trees and the pavilion’s place in a cycle of life. Students were asked to base wood system designs on the library of tectonic chunks the students had modeled previously. Drawing directly from the precedents helped students to create hierarchies of structure and screening in their design proposals. Additionally, the brief specified that the pavilions should hover above the ground, supported by ground screws, to allow for flows of water, creatures, and plants and to have a light touch on the landscape. This provided an opportunity to teach about accessibility, and a 1:12 ramp was required as part of the design.

Two examples of the ways in which wood systems factored into the students’ design work are pavilions composed of similarly sized wood members to create shade canopies, support structures, and seating for visitors. (Figure 2) Accessible ramps are embedded in the wood decks, which were modeled using sheet material to save time. The final exhibition for the arboretum pavilion project included work from all 240 of the architecture and engineering first year students. (Figures 3 and 4).

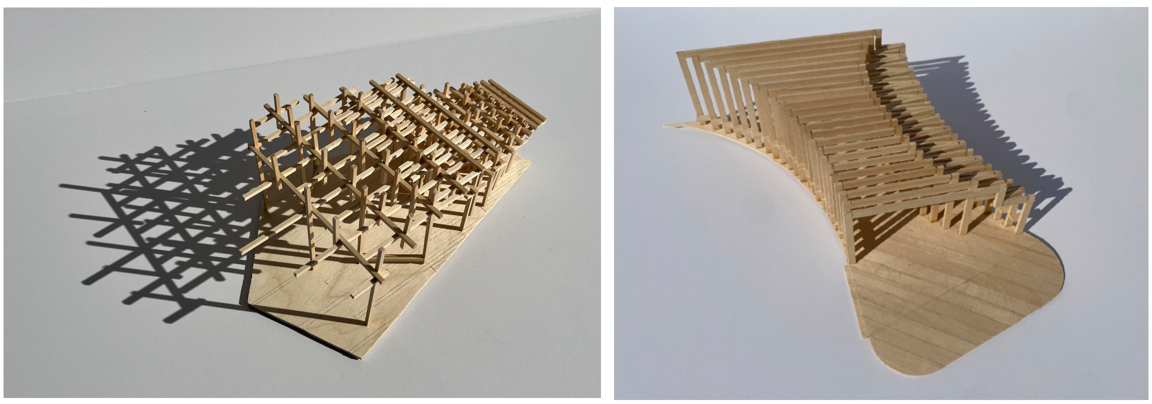
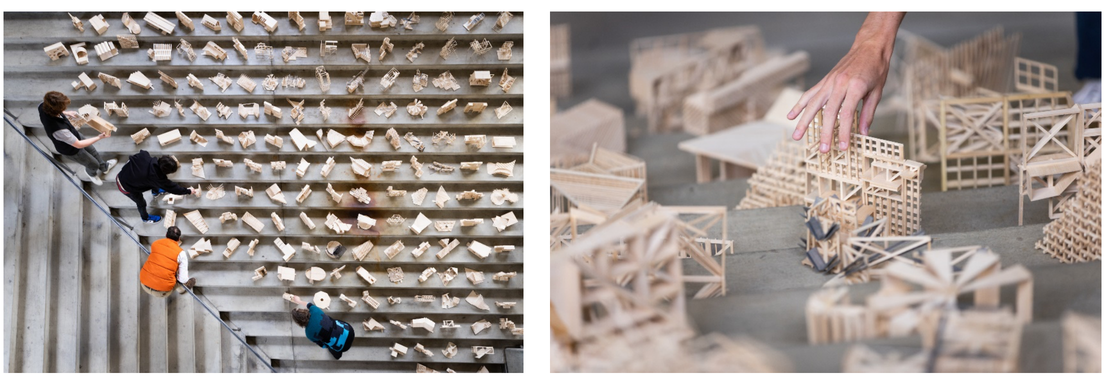


Figure 2: First Year students, Alex Jenkins and Jack Boennighausen’s speculative design for a wood pavilion for the campus arboretum. Source: (Alex Jenkins and Jack Boennighausen 2022)



Figures 3-4: Exhibition of basswood models of wood pavilions (and interior dividers). Source: (Joe Johnston, 2022)

Rather than ending the term through this speculative design project (as many design studios tend to do), the culminating project for the wood studio was a full-scale functional wood object. This contrasted with previous woodshop demonstration project assignments, which involved designing an abstract wood cube. Although the ethic of material use was part of the previous project brief—students were required to use 100% of the 4” wide, 4’-long board they were issued—the goal behind making a functional object was to encourage students to keep the objects in use. A partnership with a local urban wood forestry group, Deadwood Revival, who had recently been awarded a grant involving urban wood education and use, offered key contributions to the pedagogical arc. They brought their portable Wood-Mizer LT15 sawmill to campus to demonstrate how urban wood is sawn into slabs (Figure 5), and they also generously donated 1,000 linear feet of urban wood for students' use in the final project.

Figure 5: A local urban forester provided a milling demonstration. Source: (Clare Olsen 2022)

For this culminating project, the local forestry company supplied students with 3"-thick boards from felled urban trees, sometimes with a raw edge. Receiving the material in this state helped students to understand the source of the wood, and the responsibility to keep wood in use for carbon sequestration. The project also facilitated development of woodshop skills (a parallel goal since woodshop training is part of the first-year curriculum). Students cut boards in half on the bandsaw, planed them, and used any number of shop tools to configure "something for storing." Building on the ethic of design for deconstruction, the project brief encouraged students to construct the functional wood object with minimal or no glue, using ¼" wood dowels that were purchased in bulk and made available for the students in the woodshop. However, due to time constraints and the need to make simple joints, many students used wood dowels in conjunction with wood glue to make a durable, functional connection.

Two student work examples show storage objects that celebrate the wood's live edge. (Figure 6) Craft sensibilities are challenging to teach to a cohort of this scale. Faculty provided tips through a common hour, delivered by Keith Wiley, an expert wood craftsperson, and one-on-one advice given by studio faculty and woodshop staff. Two three-hour sessions were blocked out for each studio and although many students were able to complete their project in that time, many students also visited the shop for additional work time.

Figure 6: The "something for storing" woodshop project made from donated local urban wood. (Source: Samhita Vallamreddy and Alex Jenkins 2022)

Towards the end of the term, the authors worked with the campus arborist, Matt Ritter, and team to provide volunteer opportunities to plant trees. Over the course of three days, 78 students and four faculty participated in digging holes, planting, staking, and watering trees. (Figure 7) Dr. Ritter explained to participants that the average American needs to plant about 80 trees per year to offset their annual carbon emissions. (Skonberg 2022) Although the group did not plant anywhere close to that number, more than 20 trees were placed in the ground providing carbon draw-down, shade benefits, habitat creation, and beautification of the campus. Additionally, the planting events contributed to renewal of the university's Tree Campus USA certification.

Figure 7: Tree planting with the campus arborist, Matt Ritter. (Source: Clare Olsen 2022)

3. REFLECTION

The outcomes of the wood studio assignments and activities resonate in both pedagogical and climatological ways. One interesting result of the focus on wood as the sole material for the arboretum project is that the drawings, made in Rhino by modeling the building in three dimensions and then creating Make2d drawings, were highly articulated. Students were not permitted to use sheet material greater than 12" wide (and generally employed 2x's ranging from 2x2s through 2x12s). So this meant that the pavilion designs involved many members to create shading, screening, and a sense of privacy for the "private" component of the small program. The students were taught two methods of line weight hierarchy: near versus far, used for plans, sections, and elevations, and "spatial edge" (Ching and Juroszek), which were used for isometric drawings. Changing line weights in Rhino can be quite time consuming, but the density of linework and textures created "thick" atmospheric drawings that instilled pride in the achievement of creating drawings with a lot of content. To reduce the time and labor involved in making the pavilion models and drawings, the authors recommend including the allowance for sheet material for a portion—perhaps one third—of future iterations of the all-wood pavilion project.

Promoting craft sensibility in wood fabrication proved challenging in terms of numbers of students and time constraints, so students were encouraged to create simple designs. Yet asking students to create a functional object that they would want to keep instilled an importance of craft and an appreciation for the skills required in making wood furniture. This was the first time that the first-year students had been asked to make a functional object from wood, so it was notable that a handful of the cohort participated in the school's 19th annual furniture competition the following year. In the previous eighteen years of the competition, there had been very few second-year student entries. Only one of those received an Honorable Mention, and none had ever won a top tier monetized award. In Fall 2022, however, there were more second year entries than all previous eighteen years combined. Remarkably, out of the twelve top tier awards, three were won by second year students. In addition, one second year piece received a People's Choice award.

Another benefit of the use of local wood for the 240-student studio is that it resulted in climate benefits, even if simply looking at the fact that the school previously purchase wood from Home Depot for the woodshop demonstration project. The local Home Depot sources Weyerhaeuser wood from Oregon and Washington states, and although Weyerhaeuser practices sustainable forestry, the carbon emissions from trucking the lumber proves significant. The average semitruck gets approximately six miles per gallon. Given a 700-mile drive from Oregon, and 8.78 kilograms of carbon dioxide emitted per gallon (according to the *US Energy Information Association*), this means over 1,000 kilograms (1.1 tons) of carbon dioxide was averted by using locally sourced wood. According to Our World in Data, a U.S. resident emitted an average of 13,480 kilograms (14.86 tons) of carbon dioxide in 2021, so saving 1,000 kilograms is the equivalent of about .07 percent of what one US person generates in one year. (*Our World in Data* 2022)

CONCLUSION

The wood studio derived from a concern and responsibility to address carbon emissions and waste in the building industry and the obligation to respond to these issues through learning objectives in the first year of the curriculum for architecture and engineering students. Through local partnerships with urban wood foresters, the campus arborist, and the wood shop staff, the learn-by-doing experiences became more robust and more real. The large teaching team made use of precedent studies, speculative wood building design, and fabricating a functional wood object to teach students about basic means and methods of wood building and furniture design. Despite the practicality of these endeavours, the constraints on the assignments provided meaningful ways to engage form, representation, craft, and skill-building. The wood studio experiences and emphases on wood design and construction suggest that tackling vital concerns like environmental ethics and building industry responsibility can prove productive and fruitful for students at the start of their design education. To continue building on ethics as the foundation for design pedagogy, the next quarter in the sequence focuses on social ethics and community responsibility. A final project, which speculatively provides shelter and food security for the local unhoused community, will be piloted for the first time in Spring 2023. The quarter begins with students working in teams to design temporary full-scale structures, which they sleep in for two nights. Although this project has been integral to the pedagogy for decades, this is the first time in which the students will be asked to reflect on the act of sleeping outside to evoke empathy for those who sleep outside every day. At time of writing, the quarter has barely begun, so a future paper will report on the pedagogical methods and outcomes of this social justice framework for first year architecture and engineering design pedagogy.

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