Biomimetic Design in a Cross-Disciplinary Classroom

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The Biomimetic Design project at the University of Maryland's School of Architecture, Planning, and Preservation focuses on the general question of how to design a cross-disciplinary curriculum for architecture students around the topic of sustainability. In academic year 2020-21, the project team was represented by the disciplines of architecture, engineering, landscape architecture, and health sciences and had the unique opportunity to push innovation in curriculum planning and course implementation with support from a VentureWell Sustainable Design Faculty Grant. Coursework was centered on the design of a "biomimetic wall" and the introduction of new teaching tools employed to support students as they produced designs that mitigated and adapted to the environmental and social challenges of climate change and reduced greenhouse gas (GHG), emissions, pollution, and waste.

In this paper, the authors borrow from VentureWell's definition of environmental and social sustainability as: "Sustainable practices, innovations, products and ventures that mitigate negative impacts, and/or enable increased positive and regenerative impacts on environmental and social systems."[1] The word "biomimetic" was introduced in the curriculum planning to underscore the idea that buildings, like landscapes that photosynthesize and respire, are capable of functioning biologically to do things like mitigate air pollution, achieve net zero carbon goals, and restore ecosystems. In addition to engaging environmental mitigation technologies, buildings that are biomimetic can also inspire eco-centric perspectives of the world and heighten awareness of human impact on the natural world, which is fundamental to social change around climate adaptation.

Through a multi-week workshop organized by VentureWell, representatives from the Biomimetic Design team dug deeper into tools for teaching students about sustainability. The workshop was attended by over fifty faculty peers, professionals, and practitioners. Of particular interest to the Biomimetic Design team and discussed in more detail in this paper are the Whole Systems Mapping and estimated Life Cycle Assessment (LCA) tools discussed in the planning workshop.[2] [3] This paper reflects on the curriculum planning and discusses a variety of learning outcomes that were tested during the implementation of the graduate level ARCH 407 Architecture Design Studio IV taught by Associate Professor Jana VanderGoot, undergraduate LARC 240 Graphic Communication and Design Studio taught by Assistant Professor Naomi A. Sachs and Teaching Assistant Alison Jones, and ARCH 465 Architectural Structures II taught by Clinical Associate Professor Michael Binder at the University of Maryland in academic year 2020-21. The next steps in developing the Biomimetic Design curriculum are discussed as part of the conclusion of this paper.

LEARNING HOW TO WORK CROSS-DISCIPLINARILY THROUGH HANDS-ON CONSTRUCTION

The inspiration for the Biomimetic Design project was the curriculum planning around the award-winning 2017 US Department of Energy Solar Decathlon reACT House at the University of Maryland's School of Architecture, Planning, and Preservation. Living systems at the reACT House, including plants and regenerative technologies that provide food and ecosystem services while transforming wastes into resources, were designed and constructed as an integral part of the architecture.[4] (Figure 1) A large cross-disciplinary group of faculty and students from many units across campus, local tribe members of the Nanticoke and Lumbee and members of the Ojibwe tribe of Minnesota have shaped the reACT House project. The reACT team has continued to collaborate on sustainable design and outreach through the reACT ThinkTank, which has partnered with Piscataway tribal members since 2020. It is the Piscataway people whose traditional lands support the University of Maryland. Including voices of tribe members has made it possible for discussions all the way from preparing reACT House course modules to discussions about the role of the reACT House as a social justice hub on campus to be driven by cultural principles and traditional ecological knowledge (TEK) from these groups.

One of the most significant learning opportunities in the Solar Decathlon courses happens when students engage in hands-on construction experimentation and post-construction

Figure 1. University of Maryland Solar Decathlon reACT House, 2017.

evaluation over multiple semesters. The Decathlon is a two-year process that involves initial brainstorming and concept drawings to the construction of a physical house and finally a process of evaluation during a nine-day long competition. A defining characteristic of this hands-on work is that students learn to work in a large, ever-evolving team. The set up simulates many real-world job situations where multiple disciplines and stakeholders are involved. In this kind of cross-disciplinary setting, students have a chance to test their leadership potential, communication skills, and their ability to be flexible. The impact in terms of sustainability is also substantial. In an impact evaluation conducted by US Department of Energy on the effectiveness of this immersive Solar Decathlon experience for students, it was reported that, "…five times as many Former Decathletes have worked in the clean-energy field after leaving college as Non-decathlete Students (76% to 15%). Sixteen percent (16%) of the Former Decathletes have started businesses in the clean-energy field since leaving college compared to 2% of the Non-decathlete Students…."[5]

The UMD reACT House team continues the work of designing and constructing living systems and experiments in the built environment as an entity called the reACT Think Tank. The authors of this paper joined the reACT Think Tank in 2019. The biomimetic wall curriculum produced through the Biomimetic Design Project carries on the legacy of the reACT House as a lab space for hands on learning about sustainability in connection to climate and social justice.

In academic year 2021-22 the Biomimetic Design teaching team worked with students to implement the Phase 1 Planning portion of the Biomimetic Design coursework in which students were asked to design and prototype a "biowall" for the reACT House. The students had the opportunity to test their work using Life Cycle Assessment and Whole Systems Mapping. Students also interacted with and presented their concept drawings for evaluation to a selection of outside reviewers, including professors, fellow students, professional practitioners, and local tribe members.

One of the most challenging tasks in the Phase 1 Planning coursework was calibrating the assignments to the varied skill and maturity levels of students at different points in their education. Whereas ARCH 407 Architecture Design Studio IV and ARCH 465 Architectural Structures II are advanced graduate level courses with fewer students, LARC 240 Graphic Communication and Design Studio is an early undergraduate course with over twenty students. Assignments were structured so that the students worked in mixed teams with even numbers of graduate and undergraduate students and representation across disciplines. The cross-disciplinarity was at first a source of confusion and frustration, but ultimately for many students it became a lesson about mentorship. The team members that worked most successfully together were excited by the prospect of their roles as mentor or mentee. Faculty made sure to focus discussions less on the product and more on the process of the teamwork. A review of the post-project report where students were asked to confidentially grade themselves and their teammates revealed that teams who accepted working across age levels and disciplines gave each other higher grades, even if those grades did not so closely correspond to the quality, craft, and level of expertise shown in the architectural drawings that were part of the project deliverables.

The reACT House will be reconstructed at University of Maryland in 2022, and it is the hope that the Phase 2 Hands-on Prototyping and Construction portion of the Biomimetic Wall coursework will take place in 2023. There will be an opportunity to engage some of the same students in Phase 2.

WHOLE SYSTEMS MAPPING AND LIFE CYCLE ASSESSMENT (LCA)

The Biomimetic Design teaching team used Whole Systems Mapping and an estimated Life Cycle Assessment in tandem to start the semester and initiate students into discussions of social and environmental sustainability. Whole Systems Mapping is a way to visually lay out thoughts, set priorities, and then create multiple design iterations. Each student was responsible for designing a biowall to be constructed and tested at the reACT House. As part of the design process, each student created their own, unique definition of the term "biowall" by describing its materials (extraction, processing and construction methods), how people interact with it (the labor, the social impact), and its environmental impact in all phases of its life cycle from cradle to grave.

The course also introduced a simple do-it-yourself estimated LCA worksheet to quantify environmental impacts and compare different design options. Students referenced Ecolizer for manufacturing, transportation, and end of life use.[6] Although social impacts are factored into the Ecolizer numbers, it was more difficult to separate and understand social impacts using this tool. (Figure 2)

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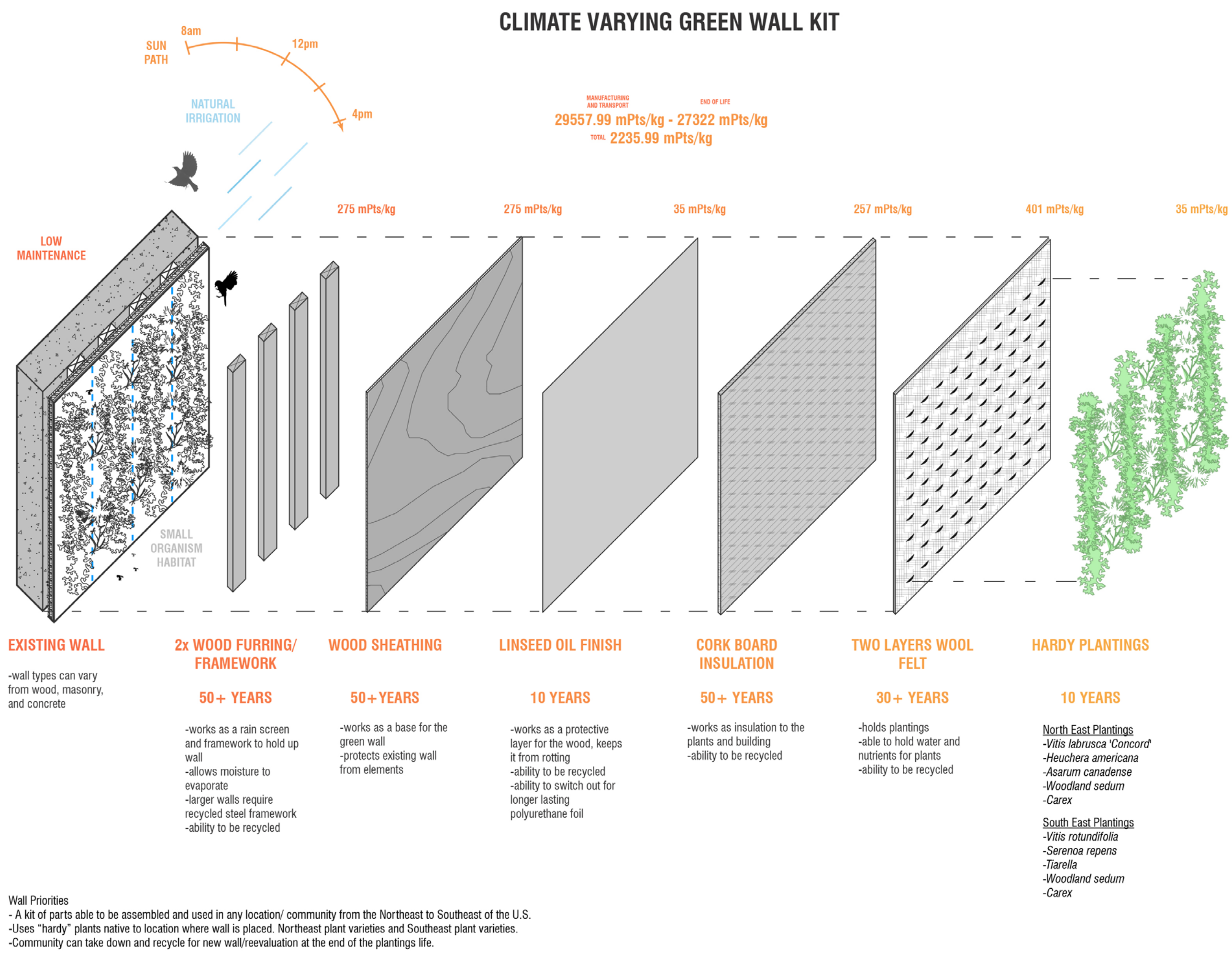

Figure 2. Exploded biowall axonometric drawing incorporating LCA metrics. Nicholas DiBella.

When polled in an anonymous mid-semester evaluation, 67% of the students self-reported that the estimated LCA tool was effective in terms of introducing systems thinking and offering them the ability to adjust their designs based on environmental impacts weighted in the LCA. The remaining 31% suggested that the case study analysis module offered in the class was the most helpful. What is worthy of note in this set of answers is that 56% percent of the answers mentioned Systems Thinking, which suggests that the Whole Systems Mapping left an impression. (Figure 3)

Interestingly, the students noted that the end-of-life use for the wall materials could either significantly increase or reduce the overall impact of the wall. This finding lead students in several new directions. Some students ramped up their explorations of more innovative, low-embodied, *living carbon materials* in their biowall designs while others decided to lightweight their walls, or reduce the amount of material in the wall. Still other students went back to their Whole Systems Map to focus on *circular economies* as a way of getting multiple uses out of a single product once it has been manufactured and thus improving the end life use metrics for that material. One biowall design student proposal employed circular economies by proposing a use for rusted scrap metal and demolition debris from construction on the University of Maryland campus. A piecemeal scaffolding was designed to be built out of strips of metal and steel re-bar and then used to grow and train willow poles. The poles of willow eventually create a living arcade connecting the reACT House to the Architecture School entrance. In three to five years, once the willow's structure is established, the scrap metal is removed and the living arcade stands on its own. (Figure 4)

JUSTICE EQUITY DIVERSITY AND INCLUSION (JEDI) IS PART OF SUSTAINABILITY

Throughout the semester the students participated in a series of guest lecture presentations that were focused on social justice, equity, diversity, and inclusion (JEDI). It is worth noting that the students in the mid-semester poll described the process of evaluating social impact and adjusting their biowall designs

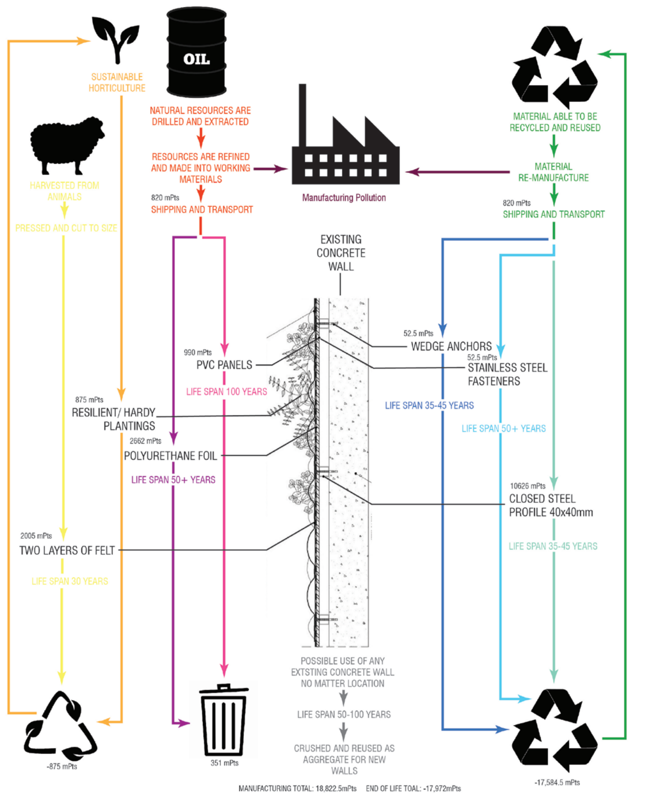

Figure 3. Whole Systems Mapping of biowall. Nicholas DiBella.

for it as more difficult than measuring environmental impact. However, after participating in the lecture series for a good part of the semester, many students were able to integrate social justice themes into their design work with more ease. A student proposal called *Gathering Materials* interpreted the idea of a biowall as a garden that would surround the reACT house. The architecture of the garden was designed to be constructed with living carbon materials from plants that are valued by the local Piscataway tribe. Pavilions and shade canopies were designed with protective skins woven out of cattail reeds, a traditional material used in indigenous structures of the Chesapeake Bay region. Birch bark was employed as a finish material to wrap low retaining walls. The walls were topped with soft mosses.[7] A Serviceberry tree was positioned at the center of the a four directions axis between North, South, East and West.[8] The idea behind the tree was that it would be a gift from the University to the Piscataway tribe. The gift would bear more gifts of berries for the community every spring. These design ideas were inspired by conversations with Rico Newman of the Piscataway Tribe and and Kyle Harmon of the Nanticoke who visited the studio as guest lecturers and spoke of gift giving as an important ceremonial gesture in building trust and respect. The tribe members also shared the idea behind a four directions garden that was incorporated into the thinking behind the reACT House Living Systems Course module. (Figure 5)

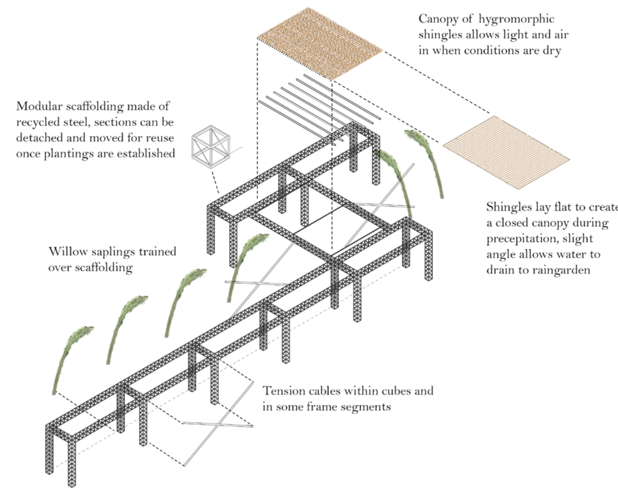

Figure 4. Circular Economy Biowall. Upasana Kaku.

In-class lecture series assignments were designed to incorporate a variety of learning methods and promote inclusive learning. For students who struggled to think visually or with quantifiable metrics, written reflections were an outlet. For students who struggled with writing, oral presentations and engagement in discussion with guest speakers became a way to express themselves verbally and discuss their work. The course also included a *service learning* component. As part of the University of Maryland Partners for Action Learning in Sustainability (PALS) program, students had the chance to work with the Prince George's County Office of Planning to imagine how the biowalls might inspire inexpensive, tactical approaches to urban development and public placemaking. In order to understand the context for their biowalls, the students conducted an abbreviated public life study using pedestrian screen line counts and stationary activity scans emphasized by the Jan Gehl Institute. The students also participated in interim workshops with planners in the placemaking division of the county offices.[9]

As hands-on, inter-personal activities around JEDI themes increased, student learning in these areas became more measurable. When polled about which presentation was their favorite, 67% of the students referenced a presentation and discussion with members of local indigenous tribes. When asked the question "Has this course changed the way you think about sustainability?" 89% students answered "Yes." 34% of students who answered who yes mentioned the phrase "social justice" in their response and 44% mentioned "systems thinking" in reference to construction "material choices."

Finally, when asked the question: "As a designer, how do you envision yourself affecting change in the area of sustainability and social justice? Where do you see yourself potentially having the most impact in your career?" 67% of students referenced social justice related work using phrases like

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Figure 5. Growing Materials biowall proposal. Almas Haider.

“community design,” “coalition building,” “social climate” and “neighborhood and community infrastructure.” The other 33% answered “affordable housing” and or “material sourcing.”

CONCLUSION AND NEXT STEPS FOR THE BIOMIMETIC DESIGN PROJECT

The course implementation experience in 2021 with two design studios and a smaller lecture course offered quite a few lessons, the most significant being that building the curriculum for the Biomimetic Design Project is necessarily a multi-year endeavor to be passed between different hands along the way and needs to be designed as such. The team size will vary as will the courses and the disciplines involved.

ENDNOTES

1. VentureWell, “Committment to Sustainanability,” accessed August 10, 2021, https://venturewell.org/faculty-grants/grant-guidelines/#sustainability
2. VentureWell, “Whole Systems Mapping,” accessed August 10, 2021, https://venturewell.org/tools_for_design/whole-systems-mapping/
3. VentureWell, “Life Cycle Assessment,” accessed August 10, 2021, https://venturewell.org/tools_for_design/measuring-sustainability/
4. University of Maryland reACT House Living Systems Module, accessed August 10, 2021, http://hdl.handle.net/1903/27604
5. US Department of Energy, Impact of US Department of Energy’s Solar Decathlon, ES.3, 2012, accessed August 10,2021, https://www.energy.gov/sites/default/files/2015/05/f22/solar_decathlon_impact_report2012.pdf
6. Ecolizer 2.0 LCA Tables, accessed August 10, 2021, https://www.ecolizer.be/
7. Moss reference: Kimmerer, Robin Wall. *Gathering Moss : A Natural and Cultural History of Mosses.* Corvallis, Oregon: Oregon State University Press, 2019.
8. Seviceberry reference: Kimmerer, Robin Wall. “The Serviceberry: An Economy of Abundance.” *Emergence Magazine,* December 10, 2020, https://emergencemagazine.org/essay/the-serviceberry/
9. Gehl Institute, Using Public Life Tools: The Complete Guide, accessed August 10, 2021, https://gehlpeople.com/tools/

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