Urban Food Systems Symposium

Lessons learned from a collaborative multidisciplinary design studio exploring urban building-integrated agriculture

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Abstract

Urban agriculture is becoming increasingly critical to promote nutritional security, community resilience, and equitable access to healthy foods for city-dwellers. However, the lack of open space and high cost of land limit the establishment of new urban farms and gardens. One innovative solution is to produce food on and in buildings through rooftop farming, green facades, and controlled environment agriculture. Sustainability co-benefits can be gained by creating a closed-loop system where building outputs are recycled as inputs to the agricultural system, and agricultural outputs ultimately provide inputs to building systems and users. Despite the promise of such building-integrated agriculture (BIA), examples of commercial BIA food production are scarce, due, in part, to the lack of an established framework to provide horticultural expertise during planning, design, and construction of buildings that have substantial crop production components. While the USDA and others have published several toolkits and guides for urban agriculture, which provide very basic resources and advice aimed primarily towards ground-based production, actionable information for architects and building owners looking to include a significant BIA component in new and retrofit construction projects is nearly nil. We posit that successful BIA design teams will likely need to have a horticultural or agricultural consultant during the design process. To explore the ramifications of this novel collaboration between two disciplines that rarely interact, University of Oregon offered an architectural design studio that engaged students enrolled in an Oregon State University special topics seminar as horticultural “consultants” during Spring Term, 2024. The site for the studio’s hypothetical project was Zidell Yards, the last remaining large parcel fronting the Willamette River in Portland, Oregon. It has a long history as an industrial ship-breaking facility and, thus, suffers from soil contamination, making it unsuitable for traditional ground-based urban agriculture. We brought in Extension professionals, practicing architects, horticultural experts, and marketing/production specialists to provide guest lectures and critiques of students’ work. By the end of the term student teams had generated innovative BIA designs that offered key social goods and ecosystem services. Several lessons were learned about the collaborative process between these disparate disciplines, including the usefulness of access to digital visual collaboration tools, the importance of prioritizing communication and trust-building, and the need to begin with shared understandings of team members’ roles and effort commitments.

Keywords

Food security, resilience, architecture, ecological engineering, horticulture, interdisciplinary, pedagogy

Disciplines

Agriculture | Architecture | Curriculum and Instruction

Presenter Information

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ABSTRACT

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"The tree tenant pays his rent with oxygen, his capacity for absorbing dust, as an anti-noise machine which produces quiet, by eradicating toxins, purification of the contaminated rainwater, as a producer of happiness and health, as a bringer of butterflies and with its beauty and in many other currencies."

—Friedensreich Hundertwasser, 1973

INTRODUCTION

Food security in a changing world

An estimated 83% of the US population currently resides in urban areas (Center for Sustainable Systems, 2023) and, consequently, the majority of food consumption in the US will also take place in urban areas. Although cities have high potential for local food production, ranging from 10% of fresh vegetable needs on public lands in Oakland (McClintock et al., 2010) to 100% on vacant lots in Cleveland, Ohio (Grewal and Grewal, 2012), rigorous accounting of food produced and consumed in cities is mostly lacking (Siegner et al., 2018). In the few cities where data exists on the spatial extent of local food production, including Portland, Oregon (McClintock et al., 2016) and Chicago, Illinois (Taylor and Lovell, 2012), researchers have found that urban agriculture is unevenly distributed, and often biased towards the more affluent regions of the city. Beyond food production, urban agricultural spaces create or support numerous other ecosystem services, including stormwater filtration (Gittleman et al., 2017), buffering against urban heat, increasing biodiversity, supporting pollinators, building healthy soil, and improving air quality. In addition, incorporating agricultural elements within buildings and urban landscapes can improve the overall visual and sensory experience of cities. The presence of living plants, natural textures, and productive greenery creates a more inviting and biophilic atmosphere, appealing to the senses and fostering a deeper connection between people and their surroundings. This can have a positive impact on the mental and physical well-being of urban residents, contributing to their overall quality of life. Finally, urban agriculture can offer economic advantages by creating new job opportunities, supporting local food economies, and contributing to the overall economic vitality of urban centers. The presence of these productive landscapes can increase the attractiveness of a neighborhood, potentially leading to increased foot traffic, commercial activity, and property values.

Despite the diverse and numerous potential benefits of urban food production, conserving and expanding urban agriculture in cities is constrained by the limited amount of open space (Taylor, 2020) and numerous competing potential uses. For example, many cities have enacted policies to reduce greenhouse gas emissions from buildings and transportation by encouraging infill development, or new construction on vacant and under-utilized lots within the urban boundaries, which are often the same lots that could provide space for community members to grow food. Unfortunately, it is difficult to justify using urban open space for crop production that is substantially less productive and more resource-intensive than conventional rural agriculture (Hawes, 2022), when increasing human population density is thought to result in greater carbon footprint reductions. However, with technologies that enable food production on and in buildings—so-called building-integrated agriculture (BIA)—which includes controlled-environment agriculture (CEA), vertical farms, and rooftop greenhouses, we may be able to recover a substantial portion of the building footprint for growing food.

High-tech indoor production in the form of vertical farms and CEA has been hailed as the next revolution in farming and a panacea for many of the woes that plague conventional farms, such as disease, pests, excess water use, adverse weather, short growing seasons, and the high carbon footprint of land conversion. Unfortunately, real-world implementation often fails to manifest significant sustainability or profitability improvements over conventional rural farming, as evidenced by recent collapses of high-profile farms and decreased interest of investors. One problem facing indoor urban producers is the considerable amount of energy needed for lighting and mechanical ventilation systems, as well as rising electricity costs. A recent peer-reviewed paper (Dimitri and Effland, 2020) discussed some of these hurdles and stated that data on successful indoor operations were quite limited. On the other hand, there are several examples of lower-tech rooftop greenhouse-based farms established over a decade ago (e.g., Lufa Farms, Gotham Greens) that continue to thrive.

Aside from simply being housed inside or on the rooftops of buildings, a more sustainable form of BIA would use building wastes (e.g., heat, CO_2, greywater, compost) as inputs for the crop production (Nadal et al., 2017; Sanjuan-Delmás et al., 2018; Muñoz-Liesa et al., 2020). By strategically designing buildings to recycle and reuse resources, such as water, waste, and energy, the agricultural and architectural components can work in tandem to create more resilient and ecologically sound urban environments. This circular approach not only reduces the environmental footprint of urban areas but also enhances the overall sustainability and self-sufficiency of these systems. Altogether, this suggests that food production in and on buildings is commercially viable and environmentally sustainable, but may require more agricultural assistance and expertise than has typically been provided to these urban growers.

Need for multidisciplinary collaboration on BIA projects

There is growing interest from architects, engineers, planners, and policy-makers in new and retrofit building construction projects that include food assets integrated into the design. For example, the City of Vancouver, British Columbia, requires new large development projects on land parcels greater than 8,000 m^2 or having 45,000 m^2 of floor area to include sustainable food assets (City of Vancouver, 2023). Unfortunately, an established framework to provide horticultural expertise during planning, design, and construction of BIA does not currently exist. While the USDA and others have published several toolkits and guides for urban farming (e.g., USDA, 2016), which provide very basic resources and advice, actionable information for architects and building owners looking to include a significant crop production in new and retrofit construction projects is nearly nil. Thus, we posit that successful BIA design teams will likely need to have a horticultural or agricultural consultant early in the conceptual design process. This falls into the category of multidisciplinary design work, which is characterized by bringing together individuals from different areas of expertise or disciplines to work together on a collaborative project (Nguyen and Mougenot, 2022). To understand some of the pitfalls and obstacles that might arise in such collaboration, we led an architectural design studio at University of Oregon (UO) concurrently with a special topics horticulture seminar entitled, “Building Integrated Agriculture” at Oregon State University (OSU) in Spring Term, 2024. Our primary goals were to:

- Conduct a pilot collaborative design studio that would help inform future similar courses;
- Glean information from multidisciplinary student interactions that will be applicable to professional designers and agricultural experts; and
- Understand some of the primary pitfalls and design challenges inherent to building-integrated agriculture.

METHODOLOGY

Students worked in multidisciplinary project teams ideally consisting of two UO architecture (hereafter ARCH) students and one OSU horticulture-related (hereafter HORT) student “consultant.” The teams developed design concepts for a future model of food production using a building as the scaffolding and setting on an urban brownfield site located in the South Waterfront District of downtown Portland, Oregon (Figure 1). The 33-acre site, dubbed “Zidell Yards,” had been used since the 1950’s as a ship-breaking and barge-building yard. Due to its long history of intensive industrial use resulting in contaminated soils, urban agriculture directly on the ground would not be possible, making BIA an attractive option. A detailed Master Plan for the entire site was conceived by Sasaki and West 8 in 2017 (https://www.sasaki.com/projects/zidell-yards-master-plan/), but was never implemented. This higher-density visioning plan was used for surrounding context, rather than the current empty lots, to encourage consideration of sunlight access with taller urban buildings nearby.

Figure 1. Hypothetical building sites for the studio outlined in cyan. Student teams were asked to choose either an adaptive re-use scheme using the larger outlined section of the existing barge building or a new construction scheme using the smaller footprint, which would entail a taller building (5–6 stories).

In addition to showcasing on-site food production, students were asked to accommodate the requirements of an imaginary client. The client was assumed to be a deli and catering company seeking to consolidate their office administrative activities with a large event space, food preparation and wellness spaces for employees, and a demonstration kitchen to support a nutrient-rich foods educational program. A key strategy emphasized in all projects was recycling building outputs as agricultural input and agricultural outputs as building and occupant input, thus creating a closed loop across as many dimensions as possible.

Architectural design studio requirements

The architectural design studio was a 6-credit course that met on Monday, Wednesday, and Friday from 1:00 PM – 5:00 PM and included both undergraduate and graduate ARCH students. Iterative and collaborative design process was heavily emphasized and rigorously documented for presentation at reviews. There were multiple opportunities for feedback during the term, including individual group crits, class pinup discussions, guest reviews, a midterm review by professionals from diverse fields (e.g., architecture, engineering, landscape architecture, city planning, horticulture, Cooperative Extension, gastronomy), and a final review with academic faculty. Students engaged in critical discussions of their work and that of their peers during studio sessions, individual "desk crits," and midterm and final reviews. The specific objectives of this course were to:

- Experiment with architectural concepts that promote food production on and in buildings;
- Use an urban site, program, and project brief, develop a coherent and elegant architectural response that synthesizes competing demands;
- Analyze site conditions as a precursor to developing building form;
- Collaborate across disciplines to develop and integrate new knowledge; and
- Articulate ideas using various methods of representation, ranging from hand-drawn sketches to detailed physical models to sophisticated digital models.

Students were given a choice of two schemes (5,574 m^2 or 2,090 m^2 footprint), the larger of which would be an adaptive reuse of the existing barge building and the smaller would be a new construction project. The ARCH students were tasked with proposing BIA designs that incorporated at least 1,400 m^2 agricultural area.

Horticulture Special Topics Seminar Requirements

HORT students, all affiliated with the university's College of Agriculture, took a 1-credit Horticulture Special Topics seminar, which met for one 50-minute session each week. The class met nine times on Mondays throughout the 11-week term. Five of the class meetings were shared with the UO class, one class meeting was a guest lecture on entrepreneurship and urban agriculture, and the remaining three class meetings were reserved for in-class discussions. HORT students were offered the option of attending three field trips, beyond regularly scheduled class time. These field trips were optional for HORT students, but mandatory for the ARCH students, and included 1) a visit to various urban agriculture sites, as well as the Zidell Yards sites (Week 1) a midterm design review (Week 5), and a final design showcase (Week 10). Throughout the term students were provided with readings relating to urban agricultural production, BIA, hydroponic production, crop selection, living walls, case studies, and regulations relating to urban agriculture. Students were also provided with videos, with topics ranging from giving effective design critiques to green infrastructure.

The HORT students were diverse in their personal backgrounds as well as their areas of study. Though all students were of Sophomore or higher undergraduate class ranking, the ages of students ranged from late teens to late twenties. This translated to a diversity in lived experiences in general, but particularly relating to agriculture. Some students had significant experience working in agriculture/horticulture, on farms and in greenhouses, and some had only small-scale garden experience. Various majors were represented, including Horticulture, Crop and Soil Science, Agricultural Science, and Ecological Engineering.

After the first week each HORT student, with the exception of one "floater" student, was assigned as a "consultant" to a team of two ARCH students based on personal experience and interest. The floater was the HORT student with the most practical experience and was available to consult with all groups as needed. During Week 7 of the term one ARCH pair split up, and the "floater" student was assigned to one of the members of the split team.

OUTCOMES & DISCUSSION

By the end of the term, this collaborative design studio bringing together ARCH and HORT student teams resulted in a diverse range of proposals for the riverfront industrial site. Given the complexity of the project brief and the time constraints of the 11-week term, the final designs were conceptual in nature, rather than well-developed construction plans. While all student teams were able to accomplish the programmatic requirements of the imaginary client, they had varying degrees of success implementing the closed-loop systems that were a key consideration. Inclusion of specific functional spaces, such as the event space and demonstration kitchen, obliged ARCH students to address issues of adjacency and circulation patterns in the building, as well as grappling with the many other competing considerations embedded in an architectural design problem. HORT students were exposed to design studio pedagogy, which features complex open-ended problems with infinite correct (and incorrect) solutions. A unique element of the design studio framework is individualized and dialogic feedback with course instructors through desk critiques, pin-ups, and review sessions at regular intervals during project development. These feedback sessions provide rich opportunities for student self-reflection—an important tool to foster a commitment to continuous learning (Coulson and Harvey, 2013).

The students' architectural design process was iterative and nonlinear. Some teams prioritized architectural form and structure first, then determined how to integrate agricultural functions later. Others took a more collaborative approach, where the design emerged iteratively through discussions with their horticulture counterparts. Decisions were made regarding how much of the building envelope would be dedicated to agriculture. Some designs prioritized maximizing the growing area, while others balanced agricultural functionality with maintaining desirable views for building occupants, highlighting how architectural decisions can both influence and be influenced by agricultural needs. Teams that engaged in a more substantive collaborative process generated final designs that were both visually striking and incorporated realistic crop production systems.

One group of students focused on a modular, structural approach to their BIA design, which proposed to retrofit the existing barge building by replacing the aluminum exterior panels with glazing (Figure 2). Their concept featured a series of stackable, reconfigurable modules that could be easily added or removed to adapt to changing agricultural needs and market demands. This modular system allowed for a high degree of flexibility and customization, with the ability to integrate various indoor farming technologies like hydroponics and vertical growing systems.

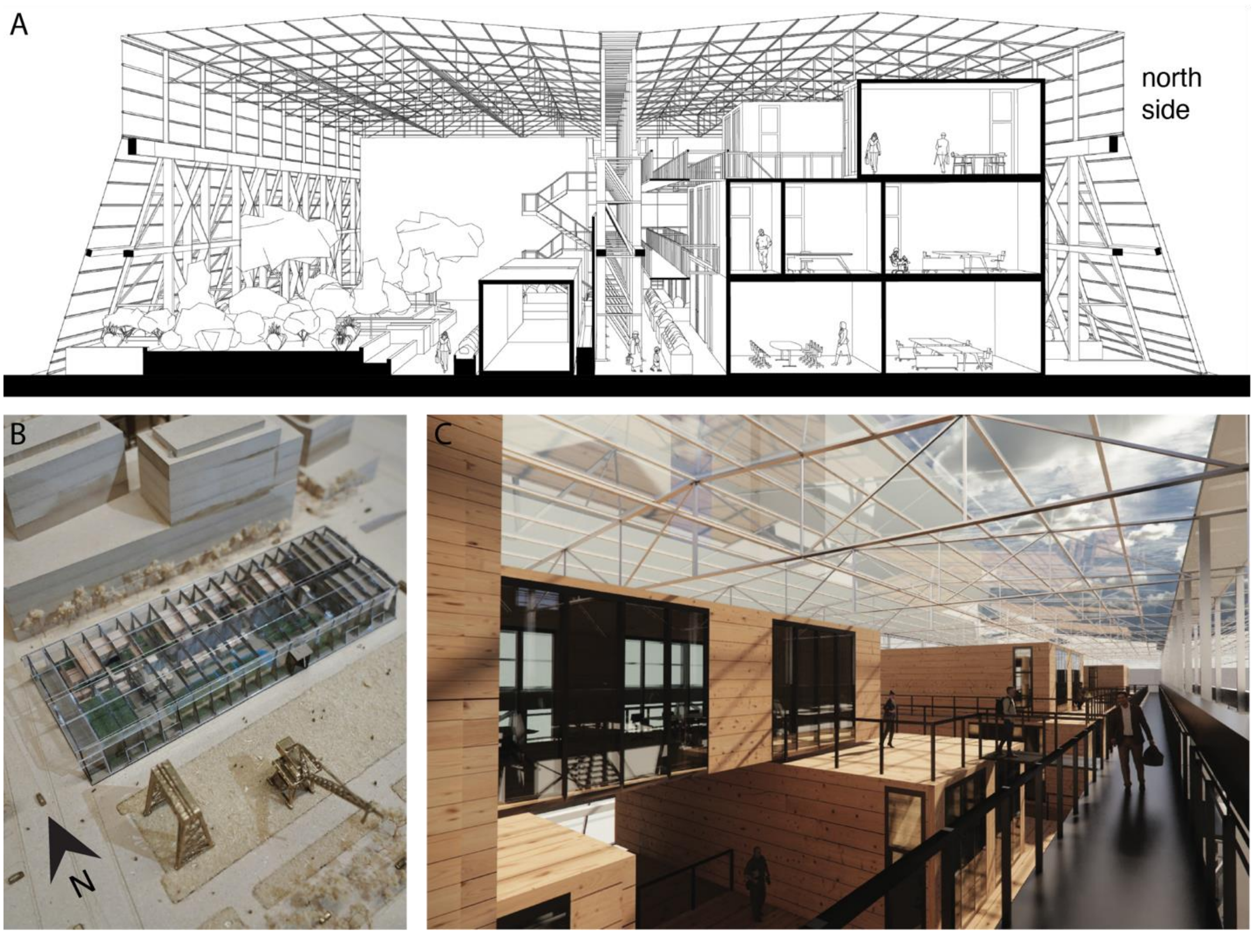


Figure 2. Team 1 design showing A) sectional perspective of final building organization with human-occupied spaces clustered toward the north side of the building and agricultural spaces on the south side for better solar access, B) final 1/32" = 1'0" building model placed in a full model of the surrounding site context, and C) interior vignette of offices rendered in a digital modeling software (Rhinoceros).

In contrast, another student team took a more organic, experiential approach to their design for adaptive reuse of the barge building (Figure 3). Their proposal centered around creating an immersive, nature-inspired environment that blended the boundaries between the built and natural elements. This included features like living walls, rooftop greenhouses, and open-air cultivation spaces that would provide a visual and physical connection to the agricultural activities for building occupants and visitors.

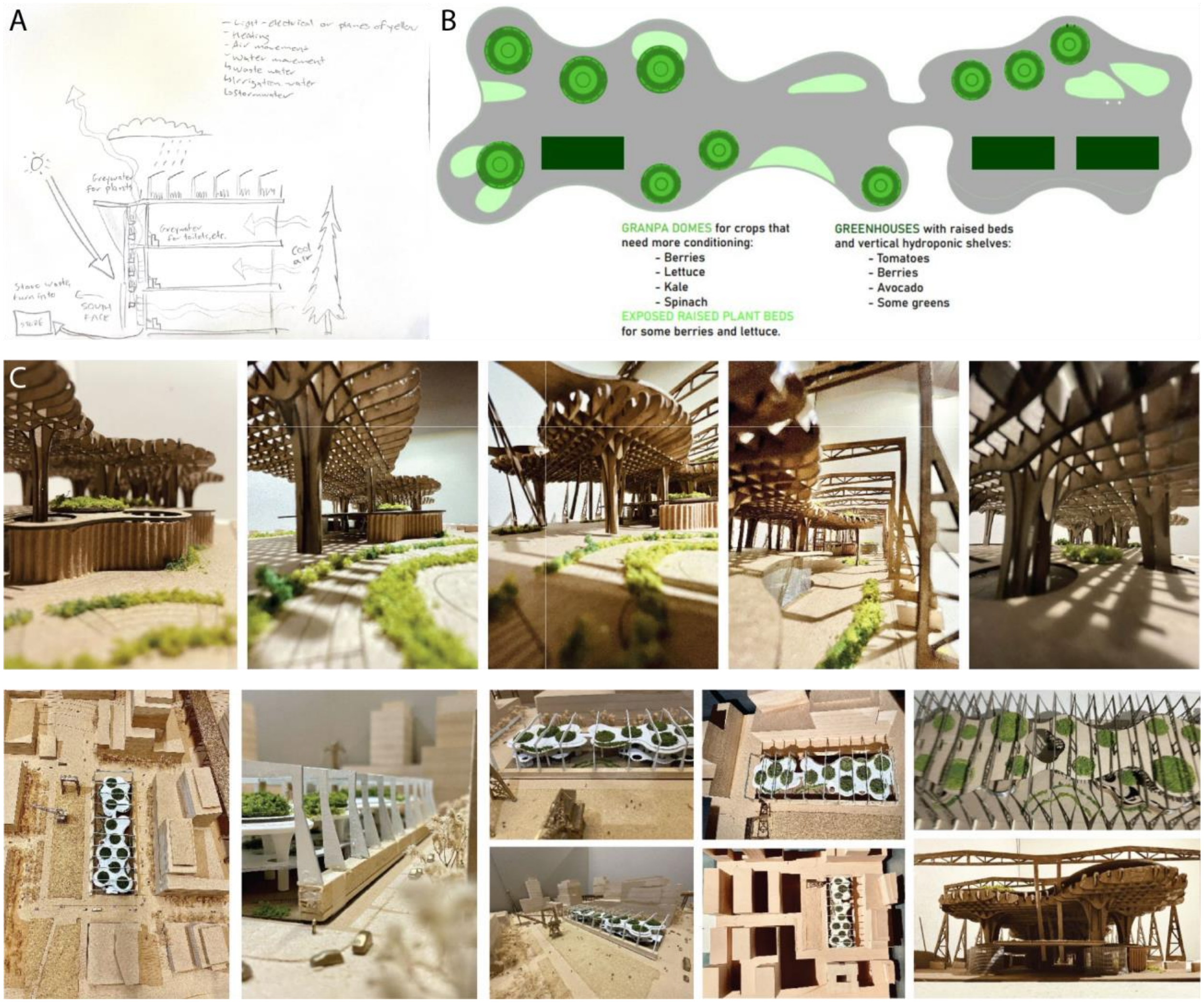


Figure 3. Team 2 design showing A) early ideation sketches, B) final organization of agricultural program using inflatable greenhouse structures known as Granpa Domes, and C) vignettes of final models at 1/16” = 1’0” (brown chipboard) and 1/32” = 1’0” (white museum-board).

Several student proposals for the smaller new construction project explored the potential of using the building's facade and exterior spaces to integrate agriculture, such as vertical gardens and green walls that could help purify air and provide additional growing opportunities (Figures 4–6). Another new construction design focused on creating strong visual and physical connections between the interior spaces and the agricultural areas, using strategies like large windows, balconies, and open-plan layouts to enhance the integration and interaction between the built and natural elements (Figure 7).

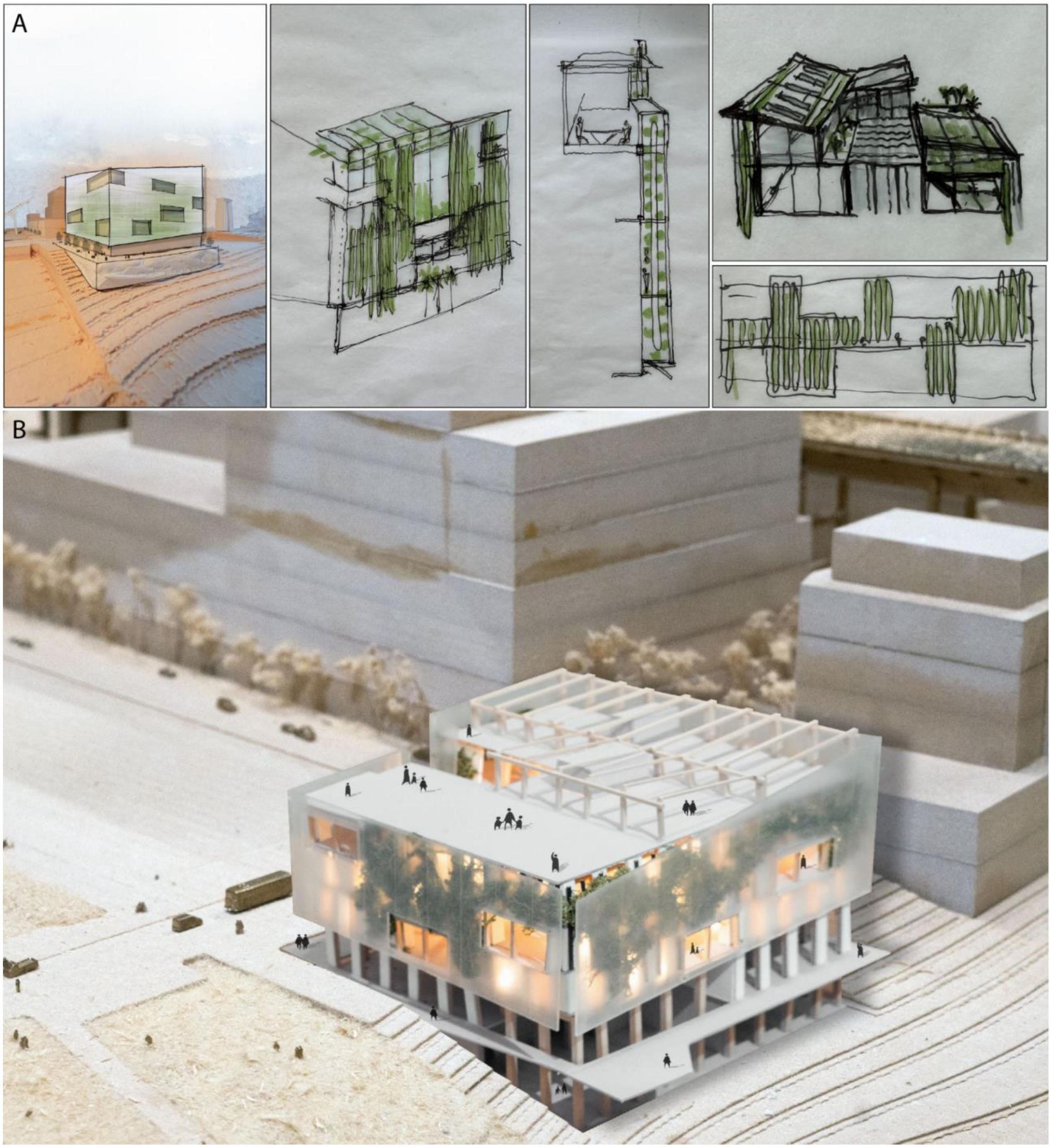


Figure 4. Team 3 design showing A) initial conceptual sketches and B) final 1/32" = 1'0" building model placed in a full model of the surrounding site context.

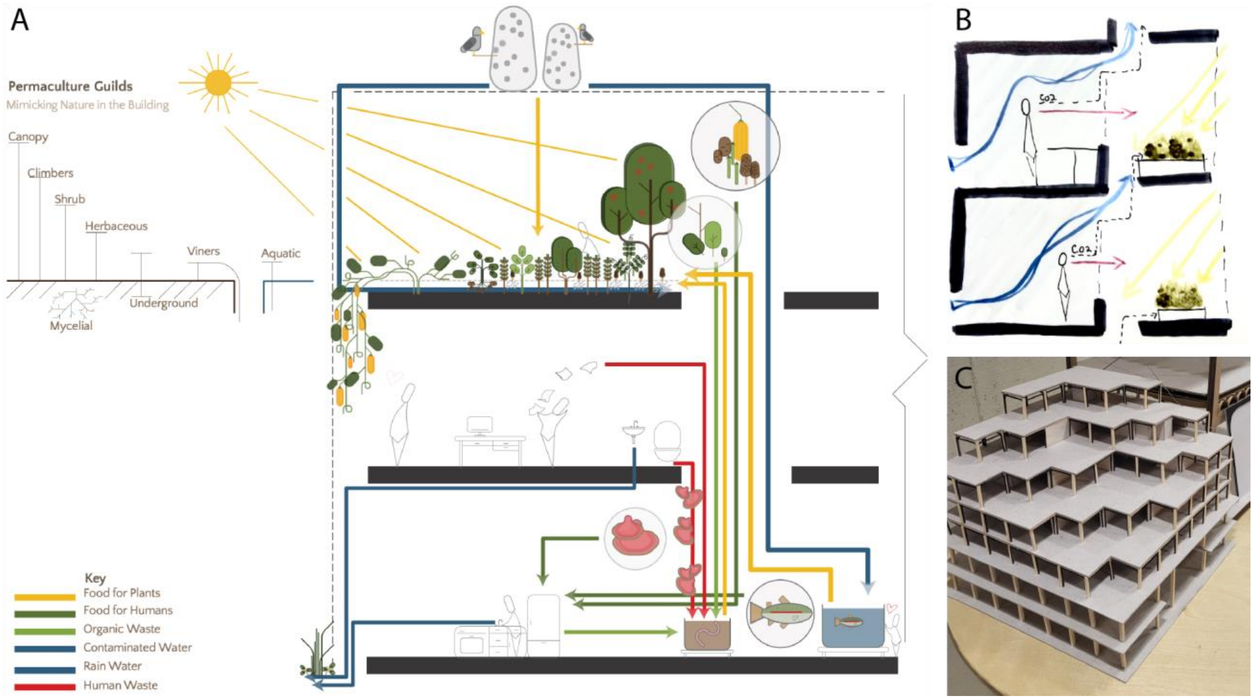
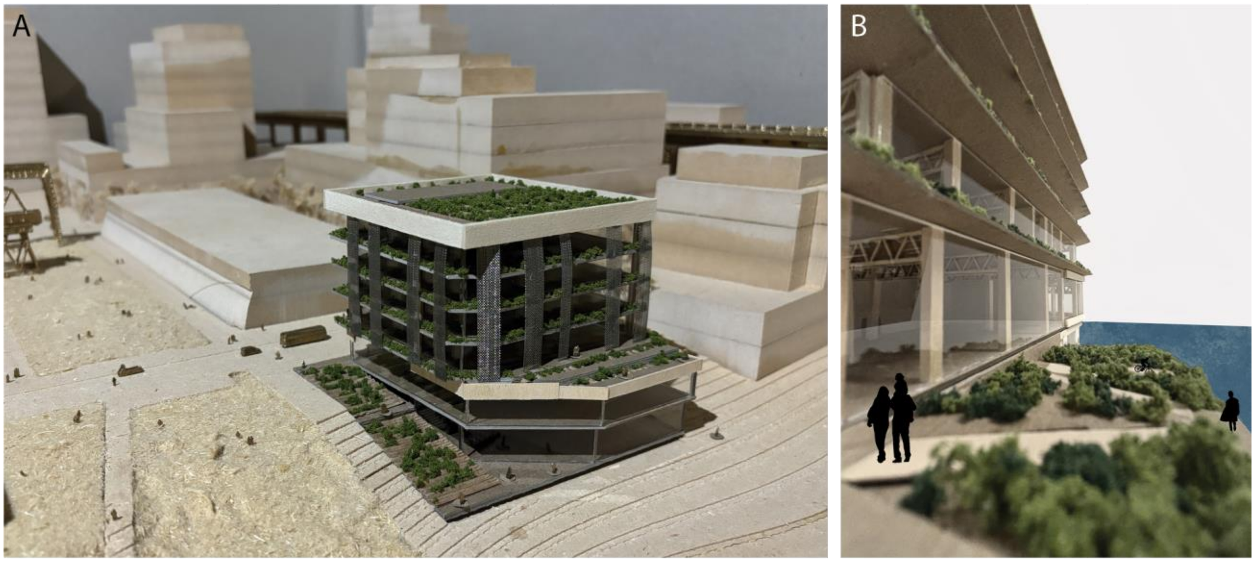
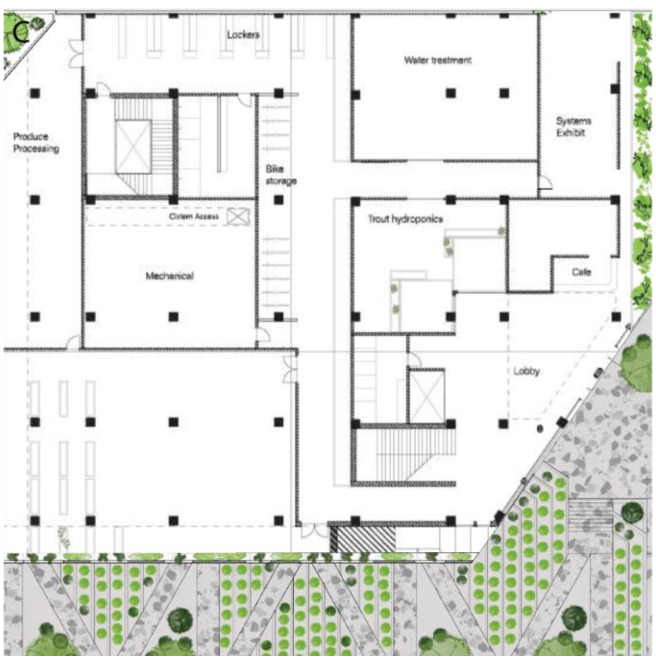


Figure 5. Team 4 design showing A) incorporation of permaculture concepts, B) sending exhaust CO_2 from human-occupied spaces into crop-growing spaces to improve plant productivity, and C) stepping design of building model to allow sunlight access for agricultural spaces on all levels of the building except the lowest two.





Plant Type	Watering	Sun	Local	Other Notes
Pepper	Frequent	Full	—	Summer crop
Strawberry	Frequent	Full	Yes	Quinault var.
Tomato	Frequent	Full	—	Summer crop
Squash	Frequent	Full	—	Vining
Peas	Average	Full	—	Vining
Beans	Average	Full	—	Vining
Nasturtium	Well-drained	Full	—	Vining
Grape	Average	Full	—	Vining
Hardy Kiwi	Overhead	Full	—	Vining
Elderberry	Average	Part	Yes	Acidic soil
Hazelnut	Well-drained	Part	Yes	Acidic soil
Blueberry	Average	Part	—	Acidic soil
Red currant	Well-drained	Full	Yes	Native var.
Huckleberry	Low-average	Full	Yes	Native var.
Cherry Tree	No overhead	Full	—	Bing & Rainier
Apple Tree	Average	Full	—	Gala
Basil	Aquaponics	Artif.	—	—
Lettuce	Aquaponics	Artif.	—	—

Figure 6. Team 5 design showing A) final 1/32" = 1'0" building model placed in a full model of the surrounding site context, B) vignette of public garden on south side of building, and C) planting plan of ground level.

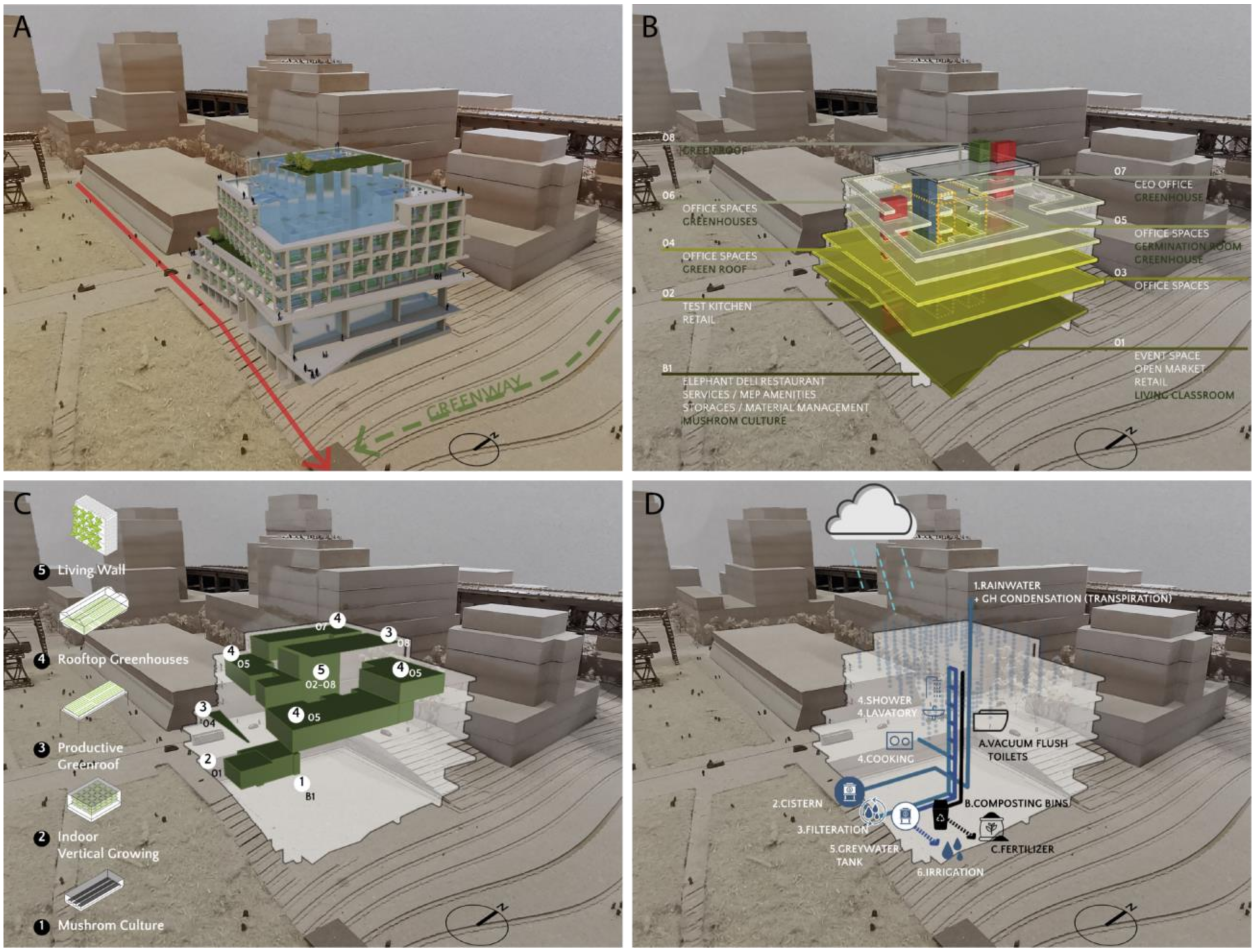


Figure 7. Team 6 design showing A) final 1/32” = 1’0” building model placed in a full model of the surrounding site context with additional information overlay, B) programmatic organization of building levels, C) typology and location of crop growing spaces, and D) water harvesting and reuse systems.

Triumphs and successes

These two concurrent courses offered students from both universities a unique opportunity to participate in a multidisciplinary design project, which allowed them to explore broader implications and applications of their own fields of study, beyond traditional architectural or agricultural contexts. This type of collaborative experience is thought to benefit students by challenging their thought processes and pushing them to work in new ways (Miles and Rainbird, 2015). The field trips were universally appreciated by both ARCH and HORT students, and allowed teams time for social interaction and getting to know each other early in the term.

Many HORT students appreciated the freedom to think outside the box, as well as the exposure to new ideas about agricultural production. Most of the courses offered within the Horticulture department, and through the College of Agriculture on the whole, are geared towards conventional methods of agricultural or horticultural production. This opportunity to be involved in the design process of a novel building-integrated agricultural production system was previously unprecedented at OSU. Several of the HORT students indicated that they especially valued first-hand exposure to the artistic process, something that is not typically included in most coursework in the College of Agriculture. These students found the architectural design process to be both interesting and inspiring.

Similarly, ARCH students felt that they benefited greatly and learned from their interactions with HORT student peers. Several ARCH students wished that there were more opportunities and more time allotted to engage with their consultants, because there was a wealth of knowledge to be shared and students did not realize what they needed to know until their continuously evolving designs spurred new questions. It was valuable to see designs evolve throughout the term, with evidence that HORT students' suggestions became incorporated into ARCH students' work.

Challenges

Despite the many successes of this course, there were also challenges for both ARCH students and their HORT collaborators. Many challenges were to be expected given the geographical distance between students of each university, cultural differences between the two disciplines, the imbalance in credit-hours for each course, students' inexperience with multidisciplinary collaboration, and the relative novelty of BIA on the whole.

Geographic differences necessitated technological solutions to facilitate collaboration. Despite the prevalence of distance-based learning and the availability of technological solutions, geographic distance still posed somewhat of a challenge. Zoom was used to facilitate the five lecture periods that were shared with both ARCH and HORT students. From both perspectives, this proved to be more challenging than anticipated. Participants often had difficulty hearing or understanding those on the other side of Zoom. Technical difficulties at the beginning of these class periods sometimes resulted in the class starting later than planned, eating into what was already a short (50 minute) class period. Students also found it difficult at times to coordinate virtual meetings outside of class, with several groups opting to instead rely on email communication. The technological challenges extended beyond Zoom meetings. Though both UO and OSU are public Oregon universities, they do not share institutional access to the same resources. For example, Dropbox is a service which UO provides to its students, but OSU does not. Additionally, for resources shared by both universities such as Microsoft Office, there were some technical issues with sharing as the collaborators were considered to be "outside of the institution." These difficulties were able to be overcome, but the process was not as seamless as it may have been. Miro, a collaborative visual whiteboard, enabled more graphic communication, but was underutilized because it did not fit well with ARCH students' work pipeline.

In addition to the technological difficulties faced, cultural differences also posed a challenge. Architecture and agriculture are two areas of study which historically have very different teaching and learning processes, as well as their own jargon. The HORT students' were generally unaccustomed to working on design projects, and often found the constantly changing parameters of the growing spaces to be difficult to conceptualize. Because of their unfamiliarity with the design process, HORT students often found it difficult to understand the general progression of the design and how agriculture was to be interpreted within it. Additionally, much of the vocabulary ARCH students used to describe their designs were new to HORT students. Several of the HORT students weren't sure how to interpret visual representations and diagrams that were shared with them. One of the most common threads across all the groups was that HORT students felt they were not given enough information to effectively advise their ARCH counterparts, and that they did not have enough time to find the information they needed. Additionally, despite its increasing popularity in recent years, there is a dearth of research relating to BIA. In terms of outdoors building-integrated agriculture, such as rooftop gardens, most built examples are in wet tropical climates or temperate climates with humid summers. Portland has a dry summer mediterranean climate, which limited the applicability of these examples to the design site. This made it difficult for the HORT students to find references and case studies or research practical applications.

Ultimately, the largest challenge was probably related to the differential credit hours between the ARCH and HORT students. This was exacerbated by the cultural differences between the architecture and agriculture students, technical difficulties, and the lack of published research relating to building-integrated agriculture. On the whole, many HORT students generally felt that they did not have sufficient time to participate in the process to the degree which they would have liked. The ARCH students met so frequently, and their designs changed so significantly week to week, that many of the HORT students found it difficult to keep up with the changes and provide meaningful advice. Additionally, because the subject matter was fairly novel, HORT students found it challenging to research the information they needed in the time they had allotted to this one-credit course. Perhaps most significantly, the differential credit hours resulted in a perpetuation of a serial, or "over the wall," method of collaboration in terms of the integration of HORT students in the process. In serial collaboration, team members independently work on portions of a project before handing it off to the next collaborator. Serial methods of collaboration can become default in multidisciplinary design collaborations, in part because it is simply easier than frequently exchanging information (Soibelman et al., 2003). This effectively is what occurred with the HORT students, whose involvement mainly consisted of awaiting information delivered to them before providing input. One ARCH team did not take full advantage of the assistance offered by their assigned HORT consultant—consequently, the final conceptual building design had comparatively little integration of agricultural systems.

Many of the aforementioned challenges faced in this multidisciplinary design process have been well-documented in related literature, but perhaps none more than those relating to communication. Communication difficulties are widely associated with multidisciplinary design collaboration. Design is a process which hinges on good communication. When working in multidisciplinary groups, the literature suggests that architecture students with the most proactive communication may produce more functional designs (Soibelman et al., 2003). Beyond design-related communication, casual conversation between group members can facilitate better understanding of different perspectives, enhancing trust and improving design outcomes (Nguyen and Mougenot, 2022).

CONCLUSION

The integration of agriculture and architecture in urban environments holds immense potential to enhance the sustainability and livability of cities and towns. By strategically incorporating agricultural elements into the built environment, designers can create synergistic relationships that can positively impact the urban fabric on multiple levels. Rooftop farms, vertical gardens, and other BIA systems can transform underutilized or vacant spaces into vibrant, food-producing oases. These agricultural interventions not only contribute to local food production but also provide opportunities for community engagement, environmental education, and the creation of new green spaces.

To successfully implement this marriage of living and built systems, it is critical to bring together experts from disparate disciplines and facilitate sharing of knowledge. Through the two concurrent academic courses described here, several key lessons were learned about the collaborative design process, including the usefulness of access to digital visual collaboration tools, the need to begin with shared understandings of team members' roles and effort commitments, and the importance of prioritizing social interactions and trust-building. Communication was an essential part of project success. Though there were some challenges associated with technology, ultimately technological solutions promoted collaboration between ARCH and HORT students. In particular, the use of visual diagrams and aids allowed many HORT students to overcome their relative unfamiliarity with architectural jargon. Additionally, the groups which were able to convene using remote digital tools with capacity to share graphics were better able to collaborate effectively. Opportunities for trust-building and getting to know each other were as important as technical design discussions. In future multidisciplinary collaborative courses, it may be useful to prioritize extra time early in the process to engage in group social activities, like field trips or low stakes brainstorming sessions, before technical discussions begin.

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