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INTEGRATED SPACE: THE NOVEL DESIGN RESEARCH EXPERIENCE

Introduction:

“From masonry bricks to multidimensional voxels, architectural design is possessed with the search for synthesis. Motivated by new scientific discoveries, such enquiries are now advancing new ways of thinking and making architecture.”[[1]](#footnote-1) New bio driven space making strategies are imperative in the 21st century. Our ability to integrate form, with material tool and system is imperative in this demanding age in which efficiency becomes essential. Bio-design, a term with a long history that was introduced and explained to the public by Neri Oxman in her 2015 TED talk, is “The use of living things such as bacteria or plants in designing products or as art”[[2]](#footnote-2) Biodesign in the urban environment creates new levels of community resilience, through allowing communities to prosper, and maintain their core residents, residents who are often displaced by the lack of healthy options in the urban environment. Biodesign when coupled with the lens of resilience becomes a strong way to maintain communities and build equity in the urban environment. In a nutshell, resilience is the staying power of a system, including buildings and neighborhoods. To create resilience, adaptation is necessary, and this can include building on the identity, values, social cohesion, and the physical environment of the system.[[3]](#footnote-3) USL Believes that bio design and resiliency are important components of the solution for retaining both people and buildings in urban settings. Through a novel indoor hydroponics system for plant growth to grow food in urban food deserts this trans-disciplinary lab works to create solutions that are both freestanding and integrated into the structure of the typical urban row home. In this process, we provide a mentoring and training experience for students focusing on creative problem-solving, science, and technology. According to United Nations Environment Program (UNEP) rapid urbanization will continue and they further predict that more than 80% of humanity will live in cities by 2050. UNEP states that planning and management of urbanization is critical, emphasis must be placed on how cities source, process, and use resources with an eye towards building resiliency in future conditions.

USL’s focus on developing an indoor plant hydroponics system powered by sustainable fertilizer contributes significantly to the choice and use of resources available for urban living. In addition, traditional science, technology, engineering and mathematics (STEM) fields in this country are currently struggling to attract sufficient numbers of students, reflected in the US ranking 27th amongst developed nations in the proportion of college students receiving undergraduate degrees in STEM. At the same time, design is becoming increasingly complex, and evidence based, with informed driven design processes becoming the new normal.[[4]](#footnote-4) USL’s approach addresses this deficiency in knowledge and hands-on experience amongst STEM and design based university graduates, while offering a solution to a pressing need. USL mentors young design professionals, researchers and scientists in the 21st century skills necessary to meet our current and near future challenges.

We train students to collaboratively engage in science, design and innovation using experiential learning, focused on designing and prototyping small and portable interior hydroponic and soil-less plant growing units that can act as decorative table-top, bookshelf or window units in an urban row home. These growing units will eventually contain nitrogen-fixing cyanobacteria to generate fertilizer for plant hydroponic growth. The design and innovation of these growing units integrates design with STEM and will provide a sustainable solution for food production for the urban population. By doing this, we will also be training a new generation of future leaders in their fields, who possess trans-disciplinary research experience(s) as part of their professional development, which will positively impact their fields of work. We have tested this innovation model with undergraduate students over a period of two years, and successfully developed several prototypes that are being tested.

URBN STEAMlab Process

Our approach addresses key social, cultural, ecological and technological factors in the following way. Once implemented in urban row homes, USL’s hydroponic system would give urban inhabitants a way to cultivate plants for food without using commercial fertilizers. This method would increase the arable “land” available for food production, and addresses the social equity topic of food availability for all urban dwellers. USL changes the culture in which research and innovation in STEM and Design occurs. USL’s trans-disciplinary model crosses disciplinary boundaries and engages students in the culture of problem-solving in a real-life setting addressing real world complex problems. Additionally, USL’s hydroponic plant growth system has a very low impact on the ecology of the region. It does not require the use of commercial fertilizers, or the use of soil. Moreover, by bringing food production into the home, the urban interior environment serves as an additional green space for its inhabitants. This green space will have a positive impact on the wellbeing of the inhabitants. USL combines the use of Design and Biology to generate a usable model for plant hydroponic growth. This combination of Biology and Design changes how technology is perceived in innovation, and crosses disciplinary boundaries.

USL’s strategy is unique in three main ways. First, it is a process that formally brings together STEM, Design research and evidence-based iteration a three pronged method that mentors a new generation of both STEM and built environment leaders. Second, USL works to create one mode of thought across multiple disciplines to establish a new knowledge base that can be drawn on to solve the complex problems driving climate change and lack of social equity in our society. USL develops trans-disciplinary problem solving as a new knowledge base for the 21st century. And third, USL examines social equity in design as the driving force for change in underserved living environments. Our project is driven by the need for there to be a safe healthy and equitable living environment for all urban dwellers. Although design is often considered a conduit for this, many in urban communities also lack access to designers, and design thinking for their living systems. Just designing for the underserved is not good enough, we must design well for them, and this requires evidence-based practice.[[5]](#footnote-5) USL will implement a human centered participatory design process that includes outreach to the community in the coming year. Drexel university has built a strong relationship with it’s neighboring communities Mantua and Powelton. The University has created an extension center that continues to drive community outreach and participation.[[6]](#footnote-6) The Mantua community is uniquely situated with a deep history, and culture. The poverty rate, is elevated in this community and it is a food desert. The neighborhood has strong leadership working to pull healthy living resources into the community. [[7]](#footnote-7) This project aims to not just provide a designed unit but to co-design with community, students, faculty, and interested parties. Planning for this co-participation process will follow the same tiered mentoring that the lab ascribes to, and may include side by side coursework in which community members and students learn together.

Our Biology-based design project includes prototyping small, portable interior plant growing units that can act as decorative units in an urban home. In these units, we use the ability of nitrogen fixing cyanobacteria to generate sustainable fertilizer for plant hydroponic growth. Certain species of cyanobacteria carry out nitrogen fixation, a process that enzymatically converts nitrogen gas obtained from the air to nitrate, that enriches the nitrogen content of the environment. We intend to harness this ability of cyanobacteria to produce fertilizer for hydroponic plant growth on a scale suitable for the urban indoor living space. Students participating in this project will be able to research/design and fabricate using 3D printing prototypes for cyanobacterial growth in urban interior spaces, test the ability of a variety of natural and synthetic prototype materials in supporting cyanobacterial growth, select for cyanobacteria that are optimized for growth in/on these natural/synthetic materials, and engage in iterative design processes. To reflect our goals, activities will be targeted to develop the novice student into a relatively independent and interdependent innovator.

Context for the URBN STEAMlab Process

Traditionally, Biology has been a laboratory-based discipline, where experiments are designed and conducted to answer pressing questions of the field and time. Key processes in experimental Biology are identification of a focus for investigation, establishing a valid hypothesis that serves as the intellectual underpinning for the experiments, designing and conducting the experiment, and analysing the results generated by the experiments. The experimental data and analysis of those data serve to establish if the original hypothesis is valid or not. When the data do not support the hypothesis, the hypothesis is not valid, and must be revised and modified, and the experiments re-designed. When the data and analysis support the original hypothesis, then a clear path for further experimentation is established. Biology and Design overlap in many of the intellectual processes they use. Hypothesis generation in Biology is equivalent to the intellectual and human centered approach of Design, by serving as the foundation of the experimental and design processes. In Biology, the design of the experimental protocol is a significant part of the experimental process, since it strongly affects the outcome. Similarly, Design takes many “experimental” factors, both human centered and environmental, into consideration to bring forth a valid outcome.[[8]](#footnote-8)

Design works iteratively, this lab uses and teaches the double diamond process that centers on diverging and converging thought in work development.[[9]](#footnote-9) Students iteratively produce options, that are assessed through a STEM lab based process and through a discussion of user driven needs, aesthetics and wants. Conducted to speculate around new forms of space making, these explorations grow from both convergent and divergent thinking models in which we work iteratively and synthesize our findings for problem-solving. Both modes are integral to design, and it is through a considered approach to these processes that we can work across traditional disciplinary boundaries. Iteration and the generation of options are key to this process and the knitting together of a design based process with a STEM lab process has created the opportunity for integrated proof on concept form the initial stages. The project currently has multiple prototypes at many scales and is working to integrate the bio needs into forms as they are deemed successful designs.

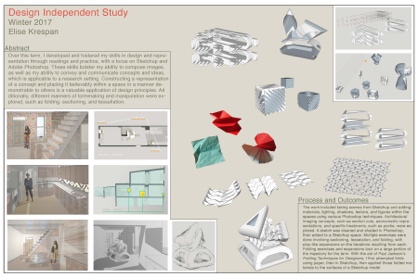
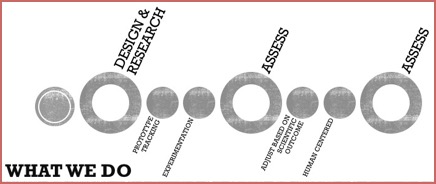


Figure 1+2 USL iteration process—where divergent and convergent thinking happen in tandem to proof of concept with student poster showing this iteration

Increased urbanization has required that food production be amplified to meet the needs of a growing urban population world-wide However, there is a limit to how much arable land can be augmented, and this limits agricultural food production. The human race need new ways to cultivate plants for food in an urban environment that is not dependent on soil. Additionally, inner city underserved inhabitants lack appropriate access to nutritional food and produce, establishing a social inequity. USL believes that new methods for addressing this social challenge are required, and that these new methods will require professionals trained in a trans-disciplinary manner in both STEM and human-centered design. Federal statistics suggests there will be a shortage of one million STEM professionals. USL approaches the national shortage in well-trained and competitive STEM students by exposing students to training in design thinking, with the support of a dedicated team of mentors. Our approach addresses and will alleviate this deficiency in knowledge and hands-on experience among STEM university graduates and professionals. Designing sustainable materials, products, and strategies for long term, environmentally friendly city living, is crucial for the overall health of the planet and its human population, and is a pillar of the USL process.

Conclusion:

URBN STEAMlab’s Impact/ Outcomes

“We must not be afraid of dreaming the seemingly impossible if we want the seemingly impossible to become a reality.” Vaclav Havel Quoted in Andres Edwards “The Sustainability Revolution” [[10]](#footnote-10) Students in USL are impacted through their experience in this novel lab. Design and creative thinking as a valuable part of spatial innovation are well established- and the need for informed research-driven practices in the design of our built environments is an expanding area with broad positive implications [[11]](#footnote-11)We recruit and train undergraduate and graduate students annually. Current USL process works across various scales and disciplines, and the structure is a rigorously defined blending of Design and STEM based techniques, skill building and iterative development. The project process includes three phases that students will move through to develop the project and deploy solutions. The first phase is Form Development, where students work to develop and deploy speculative forms based in precedent and human centered research. In the second phase, STEM lab development, students test and deploy forms based on proof of concept driven lab procedures. In the third phase, as part of Evidence Based Design (EBD) development, students test and refine based on lab outcomes, and they also circle back to the human centered work to find real world success in their projects. The project teams meet as a larger group weekly and have dedicated space in which to produce their lab and studio based works both in groups and as delegated individuals. The interaction between the students, their peers and faculty mentors highlights the importance of strong interpersonal communication in a small group setting, and model the dynamics of a work environment. This type of communication is vital for information sharing and engaging in deep problem solving to produce successful research and design outcomes.

The idea of problem solving as a multi-disciplinary community exercise in relationship to STEM project development is emphasized as an integral part of the USL process, and occurs in the weekly meetings with peers and faculty. The training and socialization process provided by USL is designed to serve as a springboard for students to identify and develop their professional identity. Our mentoring process is also an exciting opportunity to promote the leadership skills and identity of the peer group. We believe the ongoing work of our lab is the design process for the 21st century and a necessary part of our future environment design for resiliency that doesn’t break disciplinary silos, but instead makes them porous.

Bibliography

***Books:***

Chong, Gordon H., Robert Brandt, and W. Mike Martin. 2010. *Design Informed: Driving Innovation with Evidence-Based Design*. 1 edition. Hoboken, N.J: Wiley.

Cross, Nigel. 2011. *Design Thinking: Understanding How Designers Think and Work*. Oxford ; New York: Berg.

Edwards, Andres R., and David W. Orr. 2005. *The Sustainability Revolution: Portrait of a Paradigm Shift*. New Society Publishers.

***Reports:***

Mt Vernon Manor; Community. 2013. “Mantua! We Are Mantua! Choice Neighborhoods Initiative.” http://planphilly.com/uploads/media\_items/mantua-transformation-plan-1.original.pdf.

Lerch, Daniel. 2015. “Six Foundations for Building Community Resilience.” *Post Carbon Institute*. November. http://www.postcarbon.org/publications/six-foundations-for-building-community-resilience-2/.

***Paper in journal:***

Bruton, Alex. 2010. “The Venture Design Studio: A Design Thinking Approach to Teaching and Learning for the Conception, Communication and Innovation of New Venture Concepts\*.” In *ICSB World Conference Proceedings*, 1–32. Washington, United States: International Council for Small business(ICSB). http://search.proquest.com/docview/750434689/abstract/A1196B3E87E94761PQ/1.

Owen, Charles. 2008. “Design Thinking: On Its Nature and Use.” https://hbr.org/product/design-thinking-on-its-nature-and-use/an/ROT060-PDF-ENG.

Oxman, Neri. 2011. “Variable Property Rapid Prototyping.” *Virtual and Physical Prototyping* 6 (1): 3–31. doi:10.1080/17452759.2011.558588.

Website:

“An Introduction to Design For Equity.” 2015. *DESIGN for EQUITY*. http://www.designforequity.org/2/post/2015/02/part-one-an-introduction-to-design-for-equity.html.

“Definition of Biodesign | New Word Suggestion | Collins Dictionary.” 2015. https://www.collinsdictionary.com/us/submission/12064/Biodesign.

Neri Oxman Ted Talk. 2015. *Design at the Intersection of Technology and Biology*. TED talk. https://www.ted.com/talks/neri\_oxman\_design\_at\_the\_intersection\_of\_technology\_and\_biology.

“The Dornsife Center.” 2016. *Dornsife Center for Neighborhood Partnerships*. http://drexel.edu/dornsifecenter/.

1. (Oxman 2011) [↑](#footnote-ref-1)
2. (“Definition of Biodesign | New Word Suggestion | Collins Dictionary” 2015; Oxman 2015) [↑](#footnote-ref-2)
3. (Lerch 2015) [↑](#footnote-ref-3)
4. (Chong, Brandt, and Martin 2010) [↑](#footnote-ref-4)
5. (“An Introduction to Design For Equity” 2015) [↑](#footnote-ref-5)
6. (“The Dornsife Center” 2016) [↑](#footnote-ref-6)
7. (Mt Vernon Manor; Community 2013) [↑](#footnote-ref-7)
8. (Owen 2008) [↑](#footnote-ref-8)
9. (Cross 2011) [↑](#footnote-ref-9)
10. (Edwards and Orr 2005, 1) [↑](#footnote-ref-10)
11. (Bruton 2010) [↑](#footnote-ref-11)