Board 106: A Student Experiential Learning Program: An Interdisciplinary Approach to Sustainability

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A Student Experiential Learning Program – An Interdisciplinary Approach to Sustainability

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Abstract
In alignment with United Nations 17 Sustainable Development Goals (SDGs), the Center for Urban Agriculture and Sustainability (CUAS) at the University of Houston-Downtown brings together students from various disciplines and educates them on sustainability in an urban environment, teaches them about renewable energy sources and associated technologies, provides opportunities to students to produce goods and food in a sustainable manner, and engages them in community service. Our focus has been on educating students on sustainable development and providing experiential learnings that contribute towards achieving UN SDGs 6, 7, 12 and 13. In this paper, the focus is on lessons learned from an eight-year long interdisciplinary collaboration that has been supported by various grants from USDA, local companies, and our university. The culmination of this collaboration has been the development of a Center for Urban Agriculture and Sustainability (CUAS), the creation of a minor program in sustainability but most importantly the collaborative efforts of students from various disciplines working together to address important societal problems. Student projects and learnings demonstrate the impact we have had and continue to have on sustainable development. Sample projects reviewed include a solar-powered water purification system, a thermal solar collector, a phone charging station, and an indoor hydroponic vertical garden.

Program Overview
The student program highlighted in this paper was funded by a USDA NIFA grant titled Support Undergraduate Sustainable Technology and Agricultural Instructional Needs (SUSTAIN) which started in 2019 and runs through 2024 at the University of Houston-Downtown. This SUSTAIN program built off a previous USDA NIFA funded program in which the experiential learning collaboration between engineering technology and natural science first started. In this article we will showcase the highlights from the last three years of SUSTAIN, but where relevant, give take-aways from the entire eight years in which we have been engaged collaborative projects. The PI of the SUSTAIN grant (and the previous grant), Dr. Morano, is a Professor of Biology and Microbiology and the Director for the Center for Urban Agriculture and Sustainability (CUAS). The Co-PI, Dr. Tzouanas is a Professor of Engineering Technology and the Chair of the Department of Computer Science and Engineering Technology. The goals of the SUSTAIN program were to design new curriculum to support sustainability, train faculty to offer sustainability courses in hybrid or online formats, to expand experiential learning for students in agriculture and sustainability and to increase the pipeline from local high schools to the University of Houston-Downtown. This paper will focus on the innovative experiential learning program supported by SUSTAIN and what was learned over the course of the entire eight years that the authors have been collaborating on co-curricular experiential learning.

The SUSTAIN program for students at the University of Houston-Downtown has proved successful in its combination of course-work, weekly meetings with guest speakers, and

continuous mentoring through a year-long experiential learning program. Every year students in the program built a piece of technology which addresses a sustainability problem and participated in a summer internship relevant to sustainability and to the students' major. Some of these valuable features of the program were tried out in the first experiential learning program four years previously and were expanded on in the current program. Each year the program recruited eight to ten students from across all majors at the University of Houston-Downtown to participate. This means that participation in the program is diverse in majors. According to Bogoslowski [1], cross-disciplinary, project-based learning in engineering education is powerful because it forces students to participate in learning which is at higher levels of Bloom's taxonomy (synthesis, creation, etc.). Such cross-disciplinary work also forces students to synthesize perspectives from their different majors on how the project should proceed. We have observed students struggle with communication from different perspective but observed that the collaboration ultimately results in more robust solutions.

This SUSTAIN program included student collaborations between ethnically diverse groups which creates valuable cultural learning. The ethnic diversity of the cohort is typically high because the University of Houston-Downtown is a Hispanic Serving Institution (HSI) with over 50% Hispanic and also a Minority Serving Institution (MSI) with a total underrepresented minority population (Hispanic and African American) of over 70%. Such diversity allows students to gain valuable cultural capital in their interactions with each other. Research shows that group projects where students learn and work together creates cultural competency among all participants and this cultural competency is highly valued by industries and agencies, particularly those with international components [2]. Students at the University of Houston-Downtown, and more so students in programs like the one we have created, gained much desired cultural knowledge and skills.

Student applicants for SUSTAIN were engaged for the mentored program for a year. They were recruited for the year-long program in early summer. In late summer they took the course Renewable Energy Systems (SUST 3301). In the fall semester they took the course, Fundamentals of Sustainability (SUST 3302) and begin their mentored weekly meetings which had guest speakers about half the time. Guest speakers were faculty, staff or university leaders that talked about their path to success and typically covered an additional topic such as Metacognition, Imposter Syndrome, Determining Your Strength, Building a Great Resume/CV. It is our observation that these weekly required but informal meetings created a sense of belonging in students. The meetings were held in a small conference room and often started with breakfast and conversations about how everyone was doing. The addition of guest speakers proved to have a dramatic impact on students' confidence and autonomy. By having faculty and staff leadership, or a past university president tell their story of overcoming struggles, the students gained valuable insights about what creates professional success and helped them see themselves on a similar successful path.

In the fall semester students were divided into two groups to start the project phase of the program. Each group engaged in research on a group project and piece of technology that would improve a current problem in sustainability or urban agriculture. Before the spring semester the students proposed and designed technology that would solve the problem. In addition, the technology had to run completely on renewable energy. Students developed a drawing, a timeline

for building the technology and created a supply list before they were cleared to start building. Detailed examples of sample projects are described in the next section.

During the spring, weekly meetings started with a recap of the previous week's accomplishments with the focus on lessons learned and plans for the next week. Such meetings also included discussion of how we address sustainability issues such as climate change. The overarching goal of engineering technology projects was to design technologies which also help address climate change. These conversations were facilitated by having students read essays each week out of the book *Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming* [3]. The point of these discussions was to familiarize students with all the various ways that climate change could be addressed. The strength of having these discussions over different essays in the book was to create dialogue about the possible solutions to climate change. It showed the students that there is not one silver bullet, but numerous smaller initiatives or technologies that together could alleviate the stress caused by climate change. The weekly reading and discussion before we work on projects added to group cohesiveness, engaged everyone in creative thinking and gave students optimism about how they can be part of future challenges. It was our observation, that students must have hope embedded into any program focused on increasing sustainability on the planet. There is quite a bit of sociological work looking at the interaction of optimism and action on climate change. According to Wilson [4], creating an optimistic tone is required to reduce fatalism and inaction, but Wilson notes that optimism can also be linked to inaction. A large study of Swedish young people showed that well-informed discussions created constructive hope and pro-environmental behavior, but hope linked with denial about climate change created no pro-environmental behavior [5]. With our weekly discussions we fostered well-informed discussions about how technology and other societal decisions could help us move forward in addressing climate change.

The final component of the year-long program was a short internship with a local company, non-profit or agency. The PI and co-PI worked to align internships with students based on their career goals and areas of study. The internship was 40 hours per week for five and a half weeks in the summer. The funding for this internship was the USDA-NIFA grant. The purpose of the internship was to give students a chance to engage with the larger community and get hands-on work experience. Although not a requirement of an effective experiential learning experience on campus, this was a valuable addition of this program.

Other outcomes of the program that were not directly related to the experiential learning is an expansion of sustainability-based curriculum. The creation of the courses, Renewable Energy System and Fundamentals of Sustainability led to the creation of a Minor in Sustainability. These courses are open to all students at the University of Houston-Downtown, but the Renewable Energy Systems has recently been added as a degree plan option in Engineering Technology degrees. Creation of undergraduate curriculum triggered conversations about creating a graduate certificate in sustainability.

Program Assessment

As part of the SUSTAIN program students were evaluated through surveys at the start, mid-point and end of the program by an external program evaluator. Through these numerous surveys we documented student self-assessment of their change in knowledge and skills. After a year in the

program most students (usually seven out of eight or eight out of eight) reported the program influenced their career area and their level of confidence pursuing a career area. Students as a cohort dramatically increased their confidence in how to prepare an academic poster, participate in a professional meeting, plan a controlled experiment, engage in an effective mentoring relationship, find an internship that matched their interests and explore graduate degrees that interest them. At the start of the program students are asked if they were confident about describing topics such as components of the sustainability triangle, explaining how biodiversity creates ecosystem services on which we depend, articulate the human role in climate change, articulate the challenges of creating a global food production system that is sustainable, explain the role of poverty, education and healthcare in creating a sustainable system and describe the UN Sustainable Development Goals (SDCs). Their confidence at describing the above at the start of the program was typically between 40-80% depending on the topic and the year but rose to 100% on all topics by the end. Interestingly there is academic work showing that increasing knowledge about disciplines outside of the primary one someone is comfortable with, can be incredibly useful when people in those disciplines later work collaboratively [6]. Our evaluation showed that this co-curricular program is improving student knowledge and student confidence. We have also observed this shared knowledge acquisition about sustainability helped students work collaboratively on their shared projects.

Experiential learning is at the heart of the SUSTAIN program. Experiential learning is defined as learning that is accompanied by first-hand experience with real-world problem solving [7]. Effective experiential learning follows an experiential learning cycle where there is abstract conceptualization, active experimentation, concrete experience and reflection or observation [7]. Students in the program proposed and planed, built, tested, and presented their project and thus are mimicking the phases of the experiential learning cycle. It is our observation that students working together in groups grew dramatically over the course of the academic year. Students in different majors spoke different academic languages and brought different strengths. Students were also working collaboratively on something difficult that none of them had engaged in before. It was rewarding to see students grow in their confidence and their ability to work collaboratively as a team. This is a skill that employers continuously argue is important and yet is difficult to accomplish in classrooms where faculty don't usually assign long-term projects or projects as difficult in nature. Research has shown that self-efficacy increases dramatically with cross-disciplinary learning in project-based teams [8]. We observed a similar increase in self-efficacy. When asked to comment on one significant impact of the program students will take away – working as a member of a team was a common topic. Below are the take-aways by year related to what students learned with respect to working together, building confidence and/or the importance of having diverse people working together to solve complex sustainability problems.

2021

- *The skills needed to work in a team setting when long distance (over zoom).*
- *I thought that working with a diverse group of people and applying the SUSTAIN skills provided an awesome experience for me.*
- *My experiences with working with others*

- *The one lasting thing would be how to utilize the aspects of sustainability by teaming with people from all walks of life to help my community.*
- *The one thing that will always stick with me from sustain classes is learning the differences between the cultures and how sustainability could affect them in many ways.*
- *Various aspects can affect having successful sustainability, including roles and involvement of people who some wouldn't think would be part of this.*

2022

- *To have optimism for our global future. Before SUSTAIN, I genuinely thought hardly anyone cared. But being exposed to the research, practices, and new developing technology made me realize there are many people and countries striving to be sustainable which makes me have hope I didn't think I could have. Also, the importance of biodiversity and the need for complex solutions for complex problems.*
- *That even though huge world problems like climate change are overwhelming, work is being done by many to try and rectify some of the problems.*
- *That every career can be tied back to sustainability in one way or another and that in order to achieve sustainability we must think about the bigger picture rather than just focus on smaller things such as taking shorter showers and recycling.*
- *Working on a team isn't always easy but it's something to work through when one member disagrees on the team goals.*

2023

- *I just don't know what I'd do without this program. It's been a huge help for my confidence, my plans, and my sense of wellbeing.*
- *The guidance, mentorship, sense of community, and resume process are already making a huge difference.*
- *Being a part of the SUSTAIN program has actually opened my mind to more future possibilities than my future can hold. There were so many opportunities to meet interesting and ambitious individuals within the sustainability field and this was very inspiring.*
- *Being in this program has provided me an avenue to meeting individuals who have already been working in the environmental field here in Houston. I feel like I am on the path that I have been working towards.*
- *Having mentors close to me and being exposed to like-minded people and hearing their testimonies and experiences was definitely encouraging for me and did have an impact in my confidence level to just keep moving forward.*
- *Being in SUSTAIN really gave me hope that I could be finding different avenues toward pursuing a career that could benefit my community.*

This program taught valuable engineering technology skills to groups of students from all majors. These groups gained confidence that they could be involved in the creation of a technological solution, even though most they were not pursuing an engineering career. Students with a focus in engineering technology, of which we usually had two students per year, gained

valuable experience mentoring other students in some of the basics of design, but also gained valuable experience working with biology, business, psychology, and art students to bring the project to completion, to test it and effectively make the technology accessible to everyone. When faculty are asked about why experiential learning isn't brought into the curriculum, they often site obstacles such as class structure, not enough time and too much content to cover [9]. By creating a co-curricular program that meets outside of courses, we have circumvented many of these obstacles.

The internship aspect of this program was also assessed by the external evaluator and found to be successful. The focus of her evaluation was getting feedback from the community mentors the students worked with in the summer. However, when asked about the most impactful component of the program, one student commented about the impact of the internship.

- *The internship is going to stick with me for a long time, if not forever. I went in there knowing that it was going to be a project that was way over my head. I did not really know what to expect, but I proved to myself that I am very capable of managing projects, talking to people with the intention of learning more to benefit the projects, conducting the necessary research, going through trial and error, sometimes learning things the hard way, and implementing some really cool projects that I am proud of. I also met a lot of people that will be in my life for a long time. It was the most awesome experience.*

Student Projects

This section highlights projects completed by interdisciplinary SUSTAIN student teams. In many cases students were encouraged to engage in simple experiments to evaluate the effectiveness of their technology. This was in the cases where the students were able to complete the project and had time remaining in the semester for evaluation (not always the case).

1. Water Purification System Using Renewable Energy Technologies

The purpose of this project was to create a water purification system that used solar power. This project supported UN SDG #6 (Clean Water and Sanitation) and SDG #7 (Energy). According to UN, water consumption has outpaced population growth and half of the world's population is experiencing at least one month of drought per year. Due to climate change, the need for access to plentiful and clean will be more pressing in the future [10]. The system contained both reverse osmosis and UV purification. With both these systems the goal of the students was to take silty, bacterial-laden Houston bayou water and have it made drinkable. Upon the completion of the project, students tested the system using microbiological techniques. Students took bayou water and plated it on agar plates and then incubated the plates for several days. They also plated water that had run through the entire purification system. The uncleaned bayou water plates had an average of 10^6 bacterial cells/ml of bayou water and the water that went through the water purification system show no detectable bacteria. The system could purify 10 gallons of water per day. It cost about $1000 to build it. Figure 1 shows a picture of the as built system.

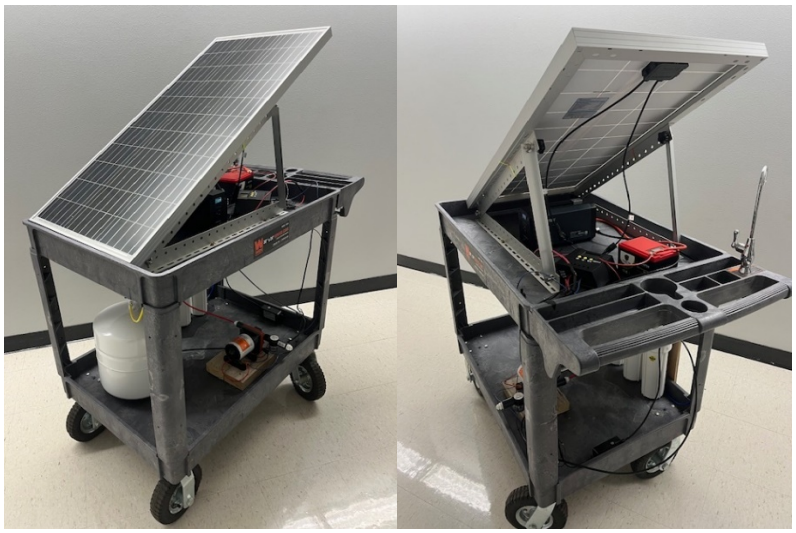

Fig. 1: Solar-powered Water Purification System.

2. Portable Cell Phone Charging Station

The basic idea behind this project was quite simple. Students would like to have access to power sources to charge their cell phones while sitting for lunch or enjoying a cup of coffee outside the main building of the university. To meet this goal, a team of students designed this portable charging station that allows eight users to simultaneously charge their phones. As part of this project, students learned about the basic components of an off-grid photovoltaic (PV) based system, how to size such a system, and ultimately how to implement technology in a user-friendly way In the current system design, energy is first stored in a battery and then inverted to AC power. Because of it, the charge time is pretty much constant. The approximate cost of the system (including the cart) is $750. Figure 2 shows the portable charging station and its major components (PV panel, charging controller, battery, and inverter).

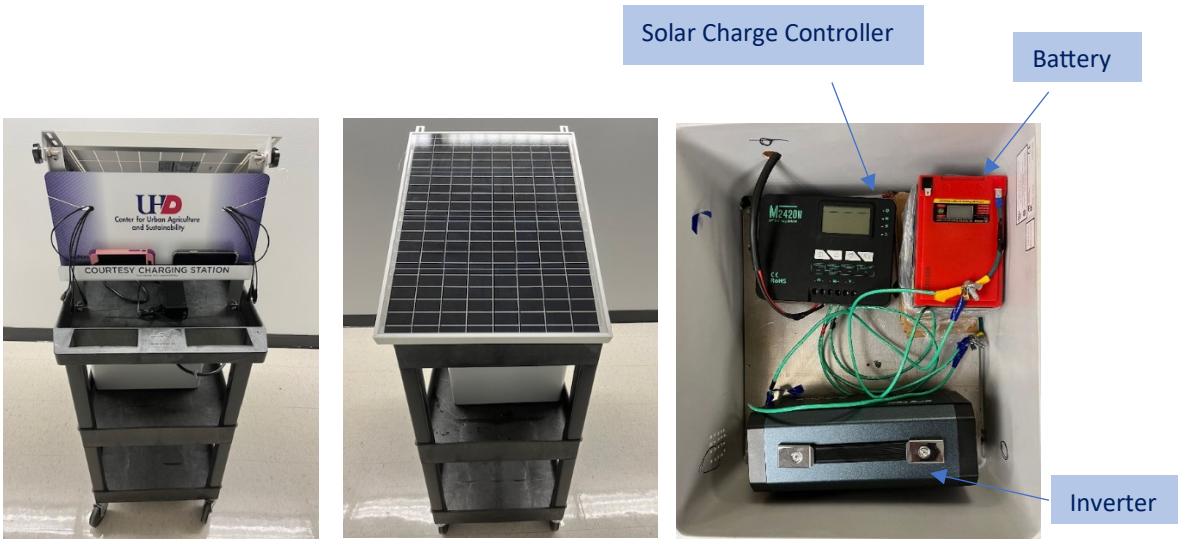

Fig. 2: Portable Cell Phone Charging Station and its Major Components

3. Solar Thermal Collector

The solar thermal collector project aimed to provide an alternative solution for the residential use of warm water by using renewable energy instead of relying on energy from expensive and unsustainable sources such as fossil fuels and coal. It is more apparent than ever before that climate change is real; thus, this project further helped lessen the impact of the greenhouse effect and supports UN SDG #7. With simple materials, students created a solar thermal collector that captures the sun's solar energy and converts it to thermal energy by heating water that circulates through the solar thermal collector. Water is circulated by using a pump that is also powered by renewable energy that is generated by converting solar energy directly to electricity using a photovoltaic (PV) panel.

By measuring temperature changes and knowing the amount of water, students estimated the rate at which solar energy is captured and converted to thermal energy. With systems like this, hot water needs can be addressed without relying on energy from non-renewable sources. Using this simple system, over a time-period of 25 min, the temperature of 10 kg of water was raised by more 8 deg C which corresponds to 337 kJ of energy collected in the form of thermal energy. Obviously, this time depends on the time of the day and availability of sunlight. The cost to build this system about $250. Figure 3 shows the solar thermal collector and its powering station that is needed to run the water circulation pump.

Fig. 3: Solar Thermal Collector

4. Indoor Hydroponic Vertical Garden

Modern agriculture contributes significantly to anthropogenic climate change and the agricultural industry is the world's second biggest emitter of greenhouse gases (GHG). Finding methods to decrease GHG emissions from agriculture would help to mitigate the effects of climate change

and is a major goal established by the UN's Climate-smart Agriculture and Sustainable Development Goals. Agricultural systems that include growing food efficiently at home can relieve the strain on the centralized agricultural system. Personalized growing can also reduce GHG emissions from transportation and increase access to fresh produce. The aim of this project was for a group to design an indoor hydroponic vertical garden that could grow hydroponic-friendly crops in an urban environment and to make the system as sustainable as possible. Materials from a purchased vertical garden system were used as the initial infrastructure. The team explored alternative growth mediums to replace the original unsustainable medium (rockwool), and the garden's nutrient source is now an organic liquid plant food. Students also powered the hydroponic garden system with solar energy. In addition, students performed several experiments to evaluate the efficacy of the garden.

Fig. 4: The vertical Garden System and Growth Pods Showing Different Mediums that Were Evaluated

In addition to biomass in each growing media, the students tested which media was most beneficial for germinating seedlings. Figure 5 shows results on sprout count out of 8 seeds for three different media type (Coco coir, 15% Rice Hulls (RH) and 85% Coco coir, 25% Rice Hulls (RH) and 75% Coco coir). Although not statistically significant ($p < 0.07$), the trend showed that high Coco coir showed greater germination rates. The cost of the hydroponic system was $850.

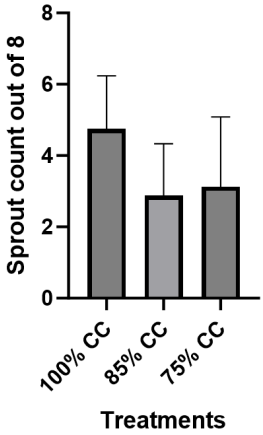

Fig. 5: Sprout count for the three different medium types.

Conclusion

This paper discussed lessons learned from an eight-year long interdisciplinary collaboration focused on sustainability and sustainable development. In this program the faculty from natural sciences and engineering technology collaborated to create an experiential learning program with content background from two courses, year-long weekly mentoring and experience designing and building a team project that runs on renewable energy. Students finished the year with an internship to gain hands-on experience and to connect with the larger community. Student projects demonstrated the type of work students performed as part of the SUSTAIN program and highlighted the knowledge and skills gained. Student feedback indicated the positive impact that the program had on their commitment to sustainability. In addition, to gaining technical knowledge, student feedback suggests significant gains in soft skills by working in an interdisciplinary team.

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