Leaky "Resilient Smart Gardens" Pilots in the Wild — An action research for improving multidisciplinary capstone projects

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***Abstract*—Millennials and post-millennials often grow up disconnected from food preparation despite the indicator of self-preparing meals being the strongest single indicator for long-term health. Up to now, our higher education system had struggled with implementing projects that help students overcome this disconnection and thereby teach them holistic approaches spanning multiple disciplines, which could also benefit their future careers. We conducted a multidisciplinary pilot between computer science and hospitality management within a senior design project class and service learning capstone class on food sustainability that implemented two versions of a resilient smart garden to compare their yield to hand-watered growing boxes. In this paper, we report on the set-up, discuss lessons learned from the pilot, and project future scenarios leveraging the sustainability transformation mindset principles that support transitioning towards teaching sustainable livelihood with the support of ICT.**

I. Introduction

Millennials and post millennials often grow up disconnected from food sourcing and preparation despite the indicator of self-preparing meals being the strongest single indicator for long-term health [19] and food sourcing having a significant impact on fruit and vegetable intake [22], [14], [13], [23], [32]. Up to now, our higher education system had struggled with implementing projects that help students overcome this disconnection and thereby teach them holistic approaches spanning multiple disciplines, which could also benefit their future careers. Growing food can help students connect to where food comes from while impacting their health and the health of the environment. However being able to grow quality food requires proper gardening techniques, In this study we focus on teaching students adequate watering practices for home gardening. Caetano et al. [4] (p. 566) state, "too little water will retard plant growth and reduce quality, while too much will leach fertilizers and reduce aeration". Adequate watering dictates the quality of the harvest, which is why we try to facilitate it by an automation that protects the user from overwatering (wasting resources) and protects the plants from drought.

To reduce an individual's outdoor water usage, researchers and practitioners have developed automated watering systems [4], [9]. However, there have been no scalable, affordable, or easily replicated solutions for people at home who lack technological skills. There are larger scale approaches for trying to grow food in the desert that need more public engagement though, so exposing students to this topic in a drought-prone region is beneficial [17].

Therefore, the purpose of this project is to engage millennials in growing food and thereby using this fresh whole food at home as well as to address the issue of food security on campus. The long-term goal of the project is to address food security issues related to lack of access and utilization. In the CSU system, one in five students do not have steady food access, creating barriers to the ability to learn [5]. Access barriers are a result of a lack affordability and/or ability to find markets with fresh produce. Barriers to utilization come from lack of knowledge, skills and/or time to source and prepare whole food [10]. The immediate outcome of this project provided fresh nutrient dense whole food to the campus food bank as well as introducing students to the taste and possible use of unfamiliar foods. In the long term, the successful implementation of the a resilient home gardening system would address these issues on a larger scale by providing an easy home gardening system to grow your on produce. An 11 episode cooking intervention, produced by the second author of this paper, can accompany the garden system to help address utilization. The 11 episode cooking show addresses barriers of knowledge, time and skills in short 15 minutes episodes.[1]

The contribution of the paper at hand is that, based on a preliminary prototype reported on in [29], we conducted a multidisciplinary pilot between computer science and hospitality management within a senior design project class and service learning capstone class on food sustainability that implemented two versions of a resilient smart garden to compare their yield to hand-watered growing boxes.

Our Resilient Smart Garden helps to ensure vegetable plants are not over or under watered. The aim is to find the water balance to grow the perfect vegetable. It also takes the mandatory watering out of the users hands and automates watering based on the moisture of the soil. The Smart Garden takes moisture and temperature readings to decide if the garden needs more water. These readings are stored in a database that is accessible online and can be accessed through PC or mobile smart phone. The data can be used to further research on the best watering method that fits for different kinds of plants.

The impact of our work is that the set-up, discuss lessons learned from the pilot, and project future scenarios leveraging the sustainability transformation mindset principles can support transitioning towards teaching sustainable livelihood with the support of information and communication technology (ICT).

II. Background

A more in-depth treatment of related work for this project is reported on in detail in [29], and therefore we report only on the most relevant research closest to our work and forming the baseline for it.

A. Food Foundations

Food security encompasses the ability of individuals, households and communities to acquire food that is healthy, sustainable, affordable, appropriate and accessible [39].

The pillars for food security indicate how well the system is taking care of its constituents by assuring food, as a public good, is accessible, available and utilizable by all citizens equally. Food insecurity, a household-level economic and social condition of limited or uncertain access to adequate food (United States Department of Agriculture) [36], is a global and national issue. According to the World Health Organization, Food security is built on four pillars:

1) Food availability: sufficient quantities of food available on a consistent basis.
2) Food access: having sufficient resources to obtain appropriate foods for a nutritious diet
3) Food utilization: appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation
4) Food stability: must be present "at all times" in terms of availability, access and utilization.

Food security is a complex sustainable development issue, linked to health through nutrition or malnutrition, but also to sustainable economic development, environment, and trade. Approximately 1 in 9 people on earth are food insecure. In the United States this equates to 49 million Americans living in food insecure households [38].

A study by Barthel and Isandahl (2012) found lessons learned from different historical and cultural contexts (the Classic Maya civilization and Byzantine Constantinople) support that urban gardens, agriculture, and water management contribute to long-term food security for people living in cities [2].

B. Related work

There are a few commercial-off-the-shelf "COTS" systems that are available in the market to help gardeners grow plants. The search led to identifying Edyn Smart Garden System [7] and GreenIQ Smart Garden Hub [9]. Both tools facilitate the gardening and irrigation but are not targeted towards educational use.

There are also a few electronic DIY projects are more accessible with easily programmable single board micro-controllers. Daniels [6] offers instructions to make an outdoor automatic garden watering device using an Arduino UNO that measures the soil moisture levels and is powered by a 12 V battery. Aqib [1] presents an advanced automatic watering garden tutorial that will store moisture, temperature, humidity, heat index, pressure, and value status into a database. The controller is powered by a 12 V battery and communicates with a server locally using an Ethernet Shield. Hamza [11] provides information on making a temperature data logger using a hardware clock. The data is stored locally on a secure digital card and does not communicate with a server. Iseman [12] demonstrates an automatic watering garden using DIY moisture sensors. Two nails are attached to a wire and connected to the micro-controller to detect the soil moisture level by putting a low current through the soil via one nail and detecting the resistance via the other. The more water in the soil, the less resistance — and vice versa. The temperature, humidity, and moisture data is sent through a serial port, but not stored into a database. The micro controller must be connected to a computer to display the data.

The Guarduino project [37] in India is most similar in design to the Resilient Smart Garden. The Guarduino uses a variety of analog and digital sensors including light, temperature, and homemade moisture sensors that are all connected to an Arduino. Similar to ours, one of the goals for this project was to help with production of food by optimizing the amount of water delivered to plants when resources are scarce.

All of these projects have similar approaches to implementing an automatically watering garden. Our Resilient Smart Garden shares some characteristics to minimize water usage

[1]http://libbyskitchen.blogspot.com, https://youtu.be/CASHB82Z6B4

while maintaining a sustainable environment for the plants. The main difference is that we perform the moisture sensing on a plant-specific basis.

C. Previous work

In [29], an extension of the results presented at the LIMITS workshop 2018 [30], the Resilient Smart Garden project is set up for the first time in an indoor lab, which allowed for more controlled variables but also turned it into an artificial environment with little natural light, thereby artificially tampering with a few variables. Previous iterations of the garden had shown that it is feasible to water completely automated, but we didn't have a comparative study that would show whether it yielded more or less than a traditionally hand-watered vegetable garden.

Multidisciplinary research is highly valued by all funding agencies in theory, and in practice there are many hurdles that need to be conquered. However, the learning experience for both sides has been insightful and merits the effort. Multidisciplinary capstone projects are an easy introduction to conducting multi- and/or interdisciplinary research but, because of the higher number of involved people, require even more organizational overhead. We saw that overhead but still thought it was a good opportunity to try out the concept and then decide whether this should be made possible for students on a wider base or only in special cases.

Our long-term vision is to integrate this with permaculture principles, where a garden built of plant guilds can foster human independence from extraneous materials and promises to deliver the highest harvest yield while making keeping the grounds sustained [20].

D. Transformation Mindset Tool

Last but not least, we applied the transformation mindset tool proposed by Samuel Mann in 2017 [16] to further analyze the opportunity for contributing to ICT4S. Mann et al. developed a Transformation Mindset [16] as a means to guide practitioners in becoming a sustainable practitioner as part of their professional framework of practice and defined the "Transformation Mindset as a way of thinking that leads to transformational acts resulting in socioecological restoration". At ICT4S 2018, he brought a DIY kit for the tool that he distributed to conference participants and the first author of this paper took it back to California and used it with her students.

III. Research Design and Methods

In the iteration presented in this paper, we added a multidisciplinary research component and teamed up with a hospitality management professor and her students to set up a comparative experiment to see whether the automated watering planters relying on the Arduino board constructions could keep up with the hand-watered planters by the hospitality management service learning team.

A. Senior design project course

The senior design project course is a capstone course over two semesters where students are in teams of three to six and develop a product from scratch. In the first semester, we usually follow a more traditional process of requirements specification, design specification, test specification and implementation. In the second semester we move to an agile model with several iterations. That way students are exposed to both common paradigms. In the second semester, students are allowed to work largely self-directed based on their previous experience from the first semester. They report back weekly and we hold reflective meetings to enhance their own analysis skills and learn from how the project unfolds [18].

B. Service learning course in hospitality management

Students enrolled in a general education capstone course called "Exploring a Sustainable Food System" are required to complete 20 hours of service in the community. In this course, students address food justice in the community. The Resilient Smart Gardens was one of the projects the students could choose to encourage home gardening as a means to increase food access in communities. Three student leaders were identified and trained to organize the daily watering, maintenance and data collection of the project. The student leaders then trained, scheduled and managed the volunteers while reporting and consulting regularly with the Supervisor of the project.

C. Experiment set-up

The comparative experiment was set up to find out whether two planters using two different implementations of the resilient smart garden idea could achieve as much harvest as the two hand-watered comparison planters. To be able to harvest after only two months, we planted two specific types of kale and romaine lettuce. It was run using a special soil developed for needing less water.

In the time line for the semester, the roles, tasks, and milestones were the following:

- *Roles:* Supervisor for the computer science students was Birgit Penzenstadler, supervisor for the hospitality management students was Libby Gustin, supporting domain expert for the gardening with the special soil was Christian Anca.
- *Tasks:* The computer science students got their implementations ready to deploy in the garden, the garden expert delivered the special soil and seedlings[2], all teams planted and put the systems in place, the hospitality management students watered their planters and took readings of all water meters (see instructions in Fig. 1, 2), the computer science students monitored their systems, and we jointly harvested at the end of the semester.
- *Milestones:* Planting and deployment on October 10th, harvest on December 7th.

[2]The semester was too short too pull the plants from seed and get all the way to harvest.

Fig. 1. Protocol A for the hand-watered planters

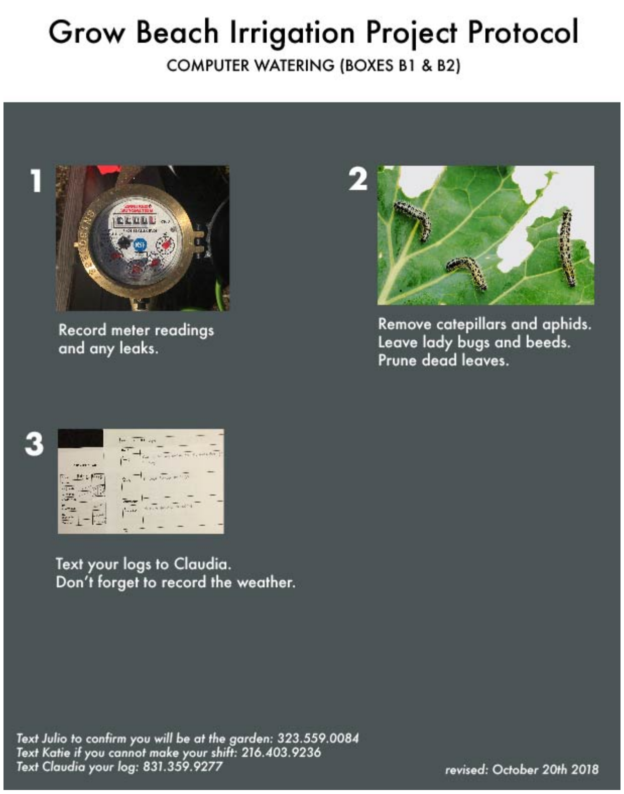

Fig. 2. Protocol B for the automatedly watered planters

The evaluation compares the amount of harvest across the planters. Furthermore, we qualitatively explore the lessons learned.

IV. Implementation and Results: Leaks and Veggies

This section describes the steps we took — application of the transformation mindset, implementation and deployment, growing and monitoring, and harvest and results.

A. Application of the Transformation Mindset

As Mann et al. [16] explain: "The mindset can be considered with a device recognisable to those familiar with software engineering's Agile Manifesto — a list of values and attributes arranged so that each is defined in part by an opposing value [8]. The agile manifesto structure finishes with 'that is, while we value the items on the right, we value those on the left more'. These things on the right then are not inherently wrong — we could find people attempting sustainability doing those things, but we argue that the things on the left are better." The Transformation Mindset can be used to consider different development initiatives.

Students analyzed the application of the Transformation Mindset principles before they went about the detailed design and the implementation. We also revisited the principles afterwards during the reflection phase.

- *Socioecological restoration over economic justification:* The resilient smart garden is a low-key, hands-on version of growing food, useful for communities.
- *Transformative system change over small steps to keep business as usual:* The idea of growing their own food instead of choosing what to buy gives students more agency.
- *Holistic perspectives over narrow focus:* The multidisciplinary project helps broaden the students' horizon.
- Equity and diversity over homogeneity: This is also one of the principles of companion planting in permaculture [20].
- *Respectful, collaborative responsibility over selfish othering:* Taking care of fellow students by donating to the food bank was appreciated.
- *Action in the face of fear over paralysis or wilful ignorance:* Growing food is empowering.
- *Values change over behaviour modifications:* The project gave students new perspectives.
- *Empowering engagement over imposed solutions:* Students can choose to grow (at least part of) their own food.
- *Living positive futures over bleak predictions:* Students perceive the opportunity as positive in the face of food deserts in the local drought-prone climate.
- *Humility and desire to learn over fixed knowledge sets:* All setbacks in the project could jointly be overcome.

B. Implementation and Deployment

The computer science students had initial prototypes from the end of the first semester of their senior design project.

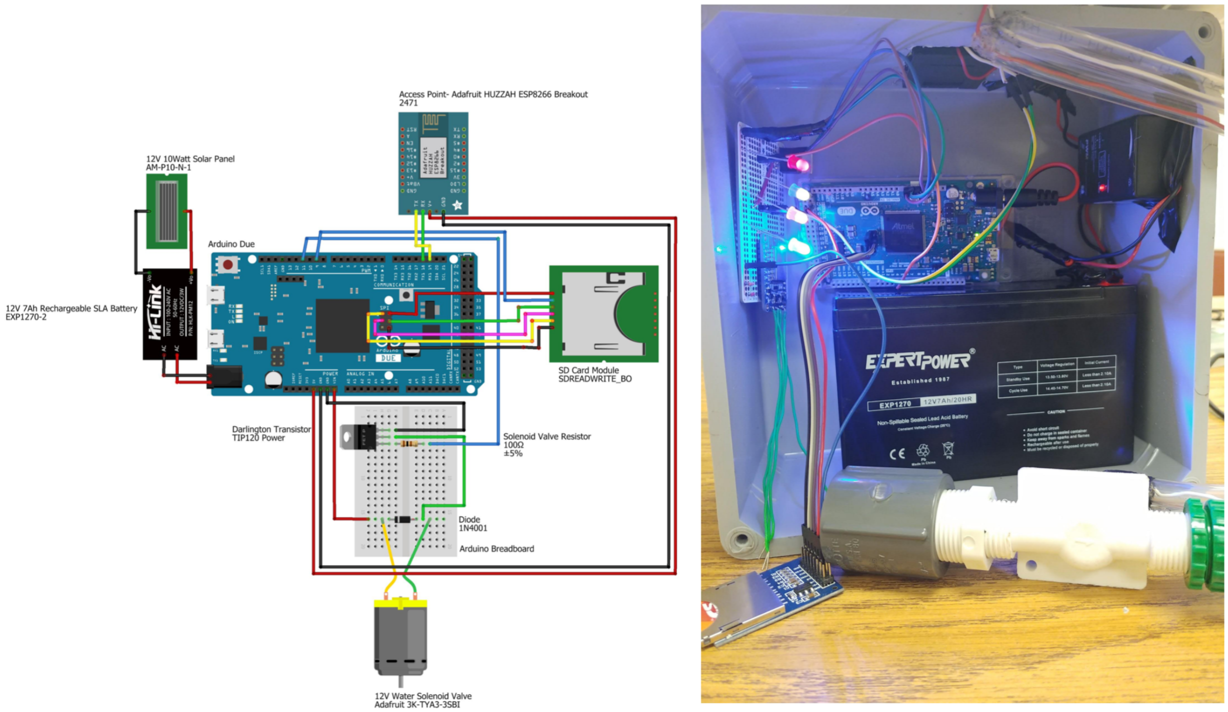

Fig. 3. Arduino monitoring system: schematic diagram on the left, and with encasement ready to be deployed on the right

However, taking those prototypes out in the wild required more effort as it turned out they didn't run stable yet. Furthermore, challenges were to connect them to a wireless module for data transmission as well as getting them connected to solar power. In addition, the databases needed to be set up and connected. All of this took them several weeks at the beginning of the semester after the initial two weeks of getting everything back up and running after the summer break and designing their individual sprint plan for the semester. Figure 3 shows one of the two prototypes before deployment "in the wild".

In the mean time, the supervisors prepared the remaining time line, purchased required hardware, and organized the delivery with the domain expert. The hospitality management students were briefed according to the protocols in Fig. 1 for the hand-watered boxes and Fig. 2 for the automatedly watered boxes.

Despite the challenges, we managed to deploy everything on October 10th with a few software updates over the following few days, see Fig. 4 for a close-up of box B2, and Fig. 5 for a closer look at box B1 with all other three boxes lined up behind and the sign asking to not tamper with out watering system in the front.

C. Growing and Monitoring

We started monitoring the systems and found a few glitches. It turned out that one of the systems was overwatering due to a not well fitting hose connector, see Fig. 7, so a puddle gathered next to the planter, see Fig. 6, that was pointed out to us by the service learning student volunteers. We fixed that, but this prototype (planter B2, Fig. 4) continued to slightly overwater despite the team repeatedly reducing the watering time. We received several emails from the student union sustainability representative over the course of the experiment asking us to make sure we are not wasting water. This box did end up using significantly more water than the other ones.

Fig. 4. Set-up of the garden experiment with sensors and automated watering

At the end of the experiment, the B1 automatedly watered planter used the same amount of water as the hand-watered planter A1 that had used less water (last readings from December 5th):

- Hand-watered box A1: 144.2 gallons
- Hand-watered box A2: 280.93 gallons
- Automatedly watered box B1: 143.33 gallons
- Automatedly watered box B2: 1022.25 gallons

While having only two boxes per type does not allow to draw

Fig. 5. Experiment with warning signs so people don't take off the hose

Fig. 6. Puddle due to over-watering at the start

Fig. 7. Leaky hose connector with ill-fitting thread

Fig. 8. Harvest on December 7th 2018

general conclusions, we see that there can be water wasted using either approach and that one of the automatedly watered boxes and one of the hand-watered boxes using almost the exact same amount of water (0.9 gallons difference) over the course of two months.

Box B1, which did well in terms of not overwatering, had a different problem though caused by the exact setting in the garden: There was a large tree overshadowing the box for a large share of the hours the sun was shining on the garden every day. Therefore, the plants did not grow as well.

D. Harvest and Results

We harvested all grown kale and lettuce on December 7th and took it to one of the kitchens in the Department of Family and Consumer Science to clean and weigh the vegetables. In Fig. 8, box B1 is being harvested by the computer science students. In Fig. 9, the entire team is standing in the hospitality management kitchen behind the cleaned produce.

Box	Vegetable	Weight	Number
A1	Kale	4.3	12
A2	Kale	5.4	9
A1	Lettuce	17.4.18	25
A2	Lettuce	17.7.8	22
B1	Kale	1.13.7	15
B2	Kale	1.8.5	10
B1	Lettuce	12.0.8	25
B2	Lettuce	10.06.3	25

TABLE I
AMOUNTS HARVESTED PER VEGETABLE PER PLANTER

The exact amounts of the harvest are listed in Table I. Overall, the hand-watered boxes delivered more produce. The number of lettuce heads and kale bunches is in the same range for all boxes, which means no plants died off after we planted the seedlings. There is a clear difference in how well the produce grew though. Both the kale harvest and the lettuce harvest amounted to significantly less weight in the automatedly watered boxes. One of the reasons for the lower amount of B1 could be that this box had less sunlight as mentioned in the previous subsection. However, as box B2 did not have that problem but achieved roughly the same amount

Fig. 9. The entire team with the harvest of the four planters

of harvest, we know that this is not the only and probably not the strongest influencing factor. Box B2 did receive too much water and as noted by Caetano et al. [4] too much water will leach fertilizers and reduce aeration, which could have impacted the low yields in this box.

After each team member was allowed to take some of the produce for personal use, we donated the remaining large part of it to the local CSULB food bank[3] for students on campus. Bringing the fresh produce to the campus food bank was not only rewarding to the students, it increased their awareness of the need for healthier food options at food banks as well as recipe suggestion and cooking skill support. As a result, all campus garden members are donating fresh produce to the food bank every 2-3 weeks. Hospitality Management students are developing simple recipes to use the food, and consulting with food bank patrons about cooking skills and utilization.

V. Lessons Learned

Around the harvest day, we sent an email to all student participants to ask for their observations and lessons learned: What were your major insights from working on the experiment? What were things you did not expect? What would you do different if you had to do it again from scratch? What else would you like us to know about your experience? We collected the answers and analyzed them to improve the project organization and management for a future replication.

A. Major insights

There were some project management insights, e.g. *This kind of project required contribution from different departments. Much like in the real world were your assigned a role in a project, however to continue and complete the project you must collaborate and communicate with others who might not being working on the same part of the project.*

Several students would have liked to have more in-person meetings across the disciplines, e.g. *Another insight I gained was that not meeting with people in person weakens communication.*

The hospitality management students reported insights on growing vegetables: *I learned about how much water really goes into growing vegetables!* and *I learned a lot about how to water and how much watering and care it takes to have successful growth and maintain a garden.*

The computer science students reported technical accomplishments, e.g. *My major insights on the experiment were the extended capabilities of the Arduino and its ability to be integrated with other technologies like the ESP 8266 WIFI module and the SD card reader module.* as well as *The understanding of the data sheets and schematics of all the components really helped when trying to get the system to function properly. Having the option to solder and learning how to do so properly, allowed for easier customization of the system in comparison to using a shield for the Arduino.* The B1 team tinkered with their system in creative ways to optimize the accuracy: *Adding resistors to the sensor system helped in the voltage drop to provide a more accurate reading, yet due to the complexity of the current being impacted the readings weren't as consistent.*

There were also a few technical challenges, e.g. *It's also extremely difficult to use a board like the Arduino and try to connect to the school's wifi because of the networks encryption protocols. Lastly, I learned it is very difficult to do weekly maintenance, which is probably why a lot of companies don't periodically release updates on a weekly basis and more often do so on a bi-weekly or monthly status.*

[3]https://www.asicsulb.org/corporate/discover/beach-pantry

B. Unexpected Things

Trouble with the readings on the water meters was reported by several students, e.g. *There were quite a few mishaps with the water meters. They were very finicky and created a lot of stress for the project.* and *One thing I did not expect was having to deal with the equipment not working properly. Having a miscommunication in dealing with this was the biggest set-back for the project by far. I also did not expect there to be a certain required level of expertise in horticulture going into the project.*

About trying to get ready for deployment, one student reports: *Originally when trying to control the water access using a solenoid valve, I had multiple attempts soldering together components to control the valve to open and close when prompted, which set back the ability to test the watering schedule.*

Furthermore, some of the sensors had problems: *We did not expect to have trouble with the data readings the sensors provided. When testing the functionality of the sensors with the Arduino, the readings were accurate to information provided on the datasheets. When wiring the sensors to the WIFI modules for the data to be passed and stored on the Arduino wirelessly, the readings for the soil moisture and UV sensors were very inaccurate.*

The student who tried to solve the over-watering problem of B2 explained: *Some things I didn't expect to occur was the constant over-watering. No matter how many times I messed around with the parameters on when to water the soil around our planter would remain moist. Even after days where the garden system didn't water the soil around the planter never fully dried. I also didn't expect to find out that it is impossible to connect to the school's wifi. Online there's all these claims where people have attempted and been able to do it. But, after attempting to connect using the same method others claimed to do online it still proved to not be possible.*

C. Do Different in Replication

Students would have wanted to up their gardening expertise ahead of time, e.g. *I would also research more on garden maintenance and how to properly take care of a garden so that we could prevent over-watering.*

Also, they'd want more interaction, e.g. *Cooperate more with the other groups/departments involved.* and *I would have liked to be in more contact myself with the engineering department about the project.* At the same time, several voted for having a smaller overall team: *Too many people have led to a lack of accountability and many misdirections in communication.* and *The number of people involved on the project should stay a little more limited to ensure more accuracy and reliability for the project.*

The potential communication improvement was best summed up by this student: *If we could start again, I would have liked to have a meeting with all of the people involved with the project, and have had one group chat and one email chain including everyone, always.*

There were suggestions for a different technical platform: *If I had to start from scratch again I would definitely choose the Raspberry Pi board over the Arduino Uno R3 because the Pi board functions as a computer with a built in module that would allow the user to log into a network as if the board was a laptop. Also the Pi is more recommended to use if your trying to complete a project that is as difficult as ours. Which required multiple components and communicating with other embedded systems.* Furthermore, the garden setting could be improved: *The plot would have done best in full sun as well as being deployed in the spring through summer. The placement of the plants and sprinkler could have been more organized and dispersed evenly for minimum amount of watering with maximum crop growth.*

D. Overall Experience

Student valued the project management experience (*It was a good chance for me to learn more about how to lead a project and how to effectively deal with people and management.*), the horticulture learning experience (*I also learned more about how to take care of crops which can help me develop my own garden eventually.*), and reported that they enjoyed being around like-minded people (*It was nice to work with people who are devoted in lessening our water usage and improving water efficiency.*).

One student pointed out the option of doing the experiment at home to save mileage: *This kind of project would be better if the student was allowed to complete the project in one of the group members home. The reason is because it would allow the group to monitor the garden on a daily basis without having to drive to school especially if they live far away. There wouldn't be any issues with the wifi regardless of what board the group uses because the user has complete control of their network.*

All students gave us positive feedback about the experience, for example *The experience as a whole was very rewarding.* as well as *Overall, it was fun visiting that part of the campus and communicating with the various people involved with this project.* Finally, several students expressed gratitude, for example *I really enjoyed being apart of something and seeing it grow. Working with Claudia and Julio was great. I feel grateful Libby trusted in us and gave us the opportunity to help run this project.*

VI. Discussion of Limitations

We seem to have run into a few classic problems of ICT4S in student and researcher projects — timescales of production are out of line with timescales of development; low-cost sensing is not robust for the environment and application; data accuracy is questionable for low-cost devices due to factory calibration (or lack thereof); and so on. We are not the first ones to experience these: Peter Lyle and colleagues reported on similar ones [15] where they conducted a study using ethnographically oriented methods of participant observation and semi-structured interviews in a community garden in the city of Brisbane in Australia. They confirm Odom's [28] findings, who points out the potential value that could be added by improving the visibility of urban agriculture projects.

There is a reasonable argument to be made about whether technology should even be trying to facilitate these small communal agricultural efforts, as put forth, for example: "Mate, we don't need a chip to tell us the soil's dry", by Odom [27], and others on a more general level on when the implication is *not* to design [3]. We strongly agree with those notions and see that the strongest reason for doing this project was to check the feasibility of having a multidisciplinary project across campus with quite a variety of stakeholders involved. In a next step, we would be approaching a local community to observe and learn and see where and how we can support by adapting technology to their needs. Granted, that is limited by the limited success our experiment was able to contribute.

Lastly, while we were enthusiastic about applying Mann's Transformation Mindset Principles during the inception phase of the project and reflected on them later on, we do see that the implementation falls short in terms of answering the bigger questions that inspired Mann's work. This could be mitigated in the future by developing an instrument that helps to tie the results of a project back into a debrief of the experience that includes a reflection of the Transformation Mindset Principles.

VII. Future Work

We used Mann et al.'s [16] sustainability transformation mindset as inspiration to draw a couple of scenarios building on what we did this semester. All of these scenarios have the common goal of developing and designing sustainable food systems [31].

A. Community garden replication

We are aiming for a replication in a Long Beach community garden, where we can interact with the general public and build further bridges between the university and parts of the local community that are not necessary likely to interact much with academia. While we would have wanted to replicate the experiment this year in the garden where the first run was conducted, the CSULB university garden will unfortunately be taken out in its current form for a new building and the future location is unclear at this point. We are currently in negotiation for the future plot.

B. Companion planting design help

In a related project, we would like to further the development of a companion planting composer software [26], [25] for capturing native, local knowledge ("the wisdom of the community"). Permaculture practitioners hold a lot of knowledge and it takes a lot of time and dedication for beginners to get to a level where they can comfortably design their own gardens. Supporting software systems could ease that learning curve for permaculture design.

C. Cooking app collaboration

In further future collaboration with hospitality management, we envision a cooking class supported by app development where cooks could capture their own recipes and have an educational platform helping them improve their skills and get feedback from each other. This collaboration faces the same time management challenges as the last one, as class times are prescribed by administration and instructors have little leeway for arranging additional mandatory meetings. Consequently, it will take a few strongly motivated and dedicated students to enable an exploration of this cross-departmental development and implementation.

VIII. Conclusion

In this paper, we reported on the set-up, discuss lessons learned from the pilot, and project future scenarios leveraging the sustainability transformation mindset principles that support transitioning towards teaching sustainable livelihood with the support of ICT. We harvested a significant amount of kale and lettuce, despite the fact that the automatedly watered boxes yielded less harvest than the manually watered ones.

While we consider the conducted action research successful in terms of experience, insights and lessons learned for all participants, we also take a critical look at the research. In the discussion of "undesigning" [33] and critiquing techno-solutionism [21], [34], we can ask whether we shouldn't just hand-water vegetables in a personal garden anyways. In our case the potential impact for education and the opportunity for a cross-university collaboration was the more important factor — and a collaboration between a computer science department and a family and consumer science department requires some technology to be involved.

Broadening to a wider perspective, we should also ask "What if sustainability doesn't work out?" [35] and work more towards resilient community building that can cope with limited resources [24].

References

[1] Muhammad Aqib. Advanced Garduino with Data Logging to Database, 2017.

[2] Stephan Barthel and Christian Isendahl. Urban gardens, agriculture, and water management: Sources of resilience for long-term food security in cities. *Ecological Economics*, 86:224–234, 2013.

[3] Eric PS Baumer and M Silberman. When the implication is not to design (technology). In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 2271–2274. ACM, 2011.

[4] Filipe Caetano, Rui Pitarma, and Pedro Reis. Advanced system for garden irrigation management. In *Advances in Intelligent Systems and Computing*, volume 353, pages 565–574, 2015.

[5] Rashida M Crutchfield. Under a temporary roof and in the classroom: Service agencies for youth who are homeless while enrolled in community college. *Child & Youth Services*, 39(2-3):117–136, 2018.

[6] D. V. Daniels. Automatic Garden Watering Device - Arduino, 2016.

[7] Edyn. Edyn, 10 October 2017.

[8] Martin Fowler and Jim Highsmith. The agile manifesto. *Software Development*, 9(8):28–35, 2001.

[9] GreenIq. GreenIq, 2017.

[10] Libby Gustin and Virginia Gray. A Sustainable Cooking Show Intervention to Address Barriers Contributing to Suboptimal Diets. *J Nutr Food Sci*, 8, 2018.

[11] Hamza, A. How to Make an Arduino Temperature Data Logger, 2017.

[12] Iseman, L. Garduino: Geek Gardening with Arduino, 2012.

[13] Jessica L Johnston, Jessica C Fanzo, and Bruce Cogill. Understanding sustainable diets: a descriptive analysis of the determinants and processes that influence diets and their impact on health, food security, and environmental sustainability. *Advances in nutrition*, 5(4):418–429, 2014.

[14] Sheila A Jones, Janelle Walter, LuAnn Soliah, and Janna T Phifer. Perceived motivators to home food preparation: focus group findings. *Journal of the Academy of Nutrition and Dietetics*, 114(10):1552–1556, 2014.

[15] Peter Lyle, Jaz Hee-jeong Choi, and Marcus Foth. Hci for city farms: Design challenges and opportunities. In *IFIP Conference on Human-Computer Interaction*, pages 109–116. Springer, 2013.

[16] Samuel Mann. A transformation mindset for computing education for sustainability. *IADIS International Journal on Computer Science & Information Systems*, 12(2), 2017.

[17] Jonathan Margolis. Growing food in the desert: is this the solution to the world's food crisis, 2012.

[18] Maira Marques, Sergio Ochoa, Maria Cecilia Bastarrica, and Francisco Gutierrez. Enhancing the Student Learning Experience in Software Engineering Project Courses. *IEEE Transactions on Education*, accepted for publication in 2017.

[19] Susanna Mills, Heather Brown, Wendy Wrieden, Martin White, and Jean Adams. Frequency of eating home cooked meals and potential benefits for diet and health: cross-sectional analysis of a population-based cohort study. *International Journal of Behavioral Nutrition and Physical Activity*, 14(1):109, 2017.

[20] Bill Mollison and David Holmgren. *Permaculture*. Lesmurdie Progress Association, 1978.

[21] Evgeny Morozov. *To save everything, click here: The folly of technological solutionism*. Public Affairs, 2013.

[22] Erin Murray, Susan Baker, and Garry Auld. Nutrition recommendations critical to teach low-income adults in efnep: Us dietary guidelines expert panel opinion. *The FASEB Journal*, 30(1_supplement):896–16, 2016.

[23] Erin K Murray, Susan Baker, and Garry Auld. Nutrition recommendations from the us dietary guidelines critical to teach low-income adults: expert panel opinion. *Journal of the Academy of Nutrition and Dietetics*, 118(2):201–203, 2018.

[24] Bonnie Nardi, Bill Tomlinson, Donald J Patterson, Jay Chen, Daniel Pargman, Barath Raghavan, and Birgit Penzenstadler. Computing within limits. *Communications of the ACM*, 61(10):86–93, 2018.

[25] Juliet Norton, Sahand Nayebaziz, Sean Burke, B Jack Pan, and Bill Tomlinson. Plant guild composer: an interactive online system to support back yard food production. In *CHI'14 Extended Abstracts on Human Factors in Computing Systems*, pages 523–526. ACM, 2014.

[26] Juliet Norton, Alex J Stringfellow, Joseph J LaViola Jr, Birgit Penzenstadler, and Bill Tomlinson. Plant guild composer: A software system for sustainability. In *RE4SuSy@ RE*, 2013.

[27] William Odom. Mate, we don't need a chip to tell us the soil's dry: opportunities for designing interactive systems to support urban food production. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems*, pages 232–235. ACM, 2010.

[28] William Odom. "you don't have to be a gardener to do urban agriculture: Understanding opportunities for designing interactive technologies to support urban food production". *Eat, Cook, Grow: Mixing Human-Computer Interactions with Human-Food Interactions*, page 177, 2014.

[29] Birgit Penzenstadler, Jayden Khakurel, Carl Plojo, Marinela Sanchez, Ruben Marin, and Lam Tran. Resilient smart gardens—exploration of a blueprint. *Sustainability*, 10(8):2654, 2018.

[30] Birgit Penzenstadler, Jason Plojo, Marinela Sanchez, Ruben Marin, Lam Tran, and Jayden Khakurel. The diy resilient smart garden kit. In *Proc. of the Intl. Workshop on LIMITS*, 2018.

[31] Ankita Raturi, Juliet Norton, Bill Tomlinson, Eli Blevis, and Lynn Dombrowski. Designing sustainable food systems. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, pages 609–616. ACM, 2017.

[32] Shannon M Robson, Lori E Crosby, and Lori J Stark. Eating dinner away from home: perspectives of middle-to high-income parents. *Appetite*, 96:147–153, 2016.

[33] M Silberman, Lisa Nathan, Bran Knowles, Roy Bendor, Adrian Clear, Maria Håkansson, Tawanna Dillahunt, and Jennifer Mankoff. Next steps for sustainable hci. *interactions*, 21(5):66–69, 2014.

[34] Yolande Strengers. Smart energy in everyday life: are you designing for resource man? *interactions*, 21(4):24–31, 2014.

[35] Bill Tomlinson, Donald J Patterson, Yue Pan, Eli Blevis, Bonnie Nardi, Six Silberman, Juliet Norton, and Joseph J LaViola Jr. What if sustainability doesn't work out? *interactions*, 19(6):50–55, 2012.

[36] USDA. What is Sustainable Agriculture?, 2018. http://www.nal.usda.gov/afsic/pubs/agnic/susag.shtml, Accessed April 9, 2019.

[37] Ankit Vashista, Harsh Rathore, and Gaurav Jain. Automatic Gardening System using Arduino. *SSRG International Journal of Electronics and Communication Engineering*, 3(8):119–120, 2016.

[38] Nancy S. Weinfield, Gregory Mills, Christine Borger, Maeve Gearing, Theodore Macaluso, Jill Montaquila, and Sheila Zedlewski. Hunger In America Study, 2014. https://www.feedingamerica.org/research/hunger-in-america.

[39] Joanne Sin Wei Yeoh, Quynh Lê, Daniel R Terry, and Rosa McManamey. Having enough cultural food? a qualitative exploration of the experiences of migrants in a regional area of australia. *J Food Research*, 2014.