ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #36613

Supporting sustainable design through holistic situated learning: A case study in transdisciplinarity

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Abstract

In 2017, a visioning committee of the National Academies of Engineering (U.S.) advocated transdisciplinary design for its potential to address complex societal needs. Lang *et al.* suggest design principles for this modality while calling for additional contributions to enrich our practice. This paper offers insights from a 10-week case study at a permaculture research site for which the lay partners report deep satisfaction and the four student participants, all female engineering undergraduates, reported transformational outcomes that support sustainable design. Some of the emergent outcomes include: Understanding engineering to be a sacred act of service, where one's actions directly affect living beings; Seeing the direct connection of one's every action to the surrounding planetary life; Experiencing a collaborative design partnership with the hosts, where the power of decision-making was shared, and solutions were co-created. Students also reported greater agency as developing engineers, authentic conflict resolution and a substantial increase in personal well-being. They reported being exhausted from their on-site projects in a way that was joyful, meaningful, and life-giving, which they contrasted with normal, academic exhaustion. The results suggest that intentionally structured, situated learning modalities can be powerful and effective for manifesting transformative outcomes in support of sustainable design. In this paper, we unpack the case study and its holistic design foundations. We also posit a theory to account for its outcomes that can guide others who would like to test these ideas in other settings.

Introduction

The National Academies of Engineering (U.S.) has advocated transdisciplinary design for its potential to address dynamically complex societal needs [1]. Sustainability is certainly one such need. One of the dilemmas about educating people to work in transdisciplinary design settings is that such settings are largely unpracticed in engineering college settings. For example, Lang *et al.* [2] offer design principles for transdisciplinary research, with these as highlights: Build a collaborative research team with shared decision-making power amongst layperson and experts; facilitate recursive, continuous understanding throughout research; work through and mitigate conflict; enhance capacity and interest in participation. These principles are almost diametrically opposed to the “normal” learning context of engineering college: hierarchical and competitive settings organized around expert knowledge; unilateral delivery of knowledge from expert to novice; team conflict avoidance resulting from the asserted necessity of the academic calendar; participation regulated by the expert teacher. Furthermore, traditional learning settings take place in the built environment rather than natural environments so that sustainability is a concept addressed at a distance. While there is most certainly variation in engineering college learning settings, we assert that in general, engineering learning environments are situations where the cultural practices are misaligned with the capacities needed for sustainable design, given its transdisciplinary nature. In other words, the means of learning is inconsistent with the desired ends. This paper offers insights from a 10-week case study at a permaculture research site for which the lay partners reported deep satisfaction and the four student participants, all female engineering undergraduates, reported transformational outcomes that support sustainable design.

We consider this case study to represent one of many incarnations that are possible to foster such outcomes. We begin with some notes on research methods and a description of the case study. The findings follow with a discussion of the conditions we believe to have contributed. We have chosen to use the third person voice below to minimize confusion. Additionally, will do not use capital letters for elizabeth west by her request.

Research Methods

The research practice used in this case study was participatory action research (PAR); participants chose to be researchers who were in action and reflecting together on their process of self-discovery and learning. As described by Ledwith [3], this method is characterized by "working with people in reciprocal, mutual relationships." It includes the distinct characteristics of "rejecting the alienating methods of scientific research; emphasising (*sic)* connection/wholeness, healing injustices; countering fragmentation of thought and action; committing to critical consciousness and action for change;...and equalising (*sic*) power in the research process and in its outcome." The PAR practiced in this study was grounded in an egalitarian disposition regarding participants and partners, which are described below.

In PAR, the researchers are also participants, so PAR is not considered human subjects research under the Common Rule (Code of Fed. Regulations) [4], however, each participant went through an informed consent process prior to starting the research and prior to the post-research interviews interviews. These semi-structured interviews were conducted by Vanasupa within three months of completing the research. The transcribed interview narratives were and analyzed by Vanasupa following the method of Strauss and Corbin [1]. The provisional analysis was socialized amongst the interviewee researchers for validation and adjustment. We note our intent in analyzing the interviews was to see patterns across the learning experience. We make no claims of generalizability, consistent with PAR; our intent is to share the patterns of this situated learning experience in hopes of providing insights to designers of other experiences.

Case Study Detail

This case study involves the participants listed in Table 1, all of whom were assigned female at birth. The site hosts are deeply experienced in working with young adults, having offered a week on Woodland Harvest Mountain Farm (WHMF) to college groups for alternative spring breaks for more than ten years. west is also a former adjunct professor of sixteen years in Women and Gender Studies at Appalachian State University. All student researchers report “loving” their home institution, Olin College of Engineering.

Table 1. List of research participants from the case study.

Name [*pronouns*]	**Role**	**Institution**
Vanasupa, Linda [*they/them/theirs* or *any*]	Principal Researcher	professor of materials engineering, Franklin W. Olin College
Phelps, Sally [*she/her/hers*]	Associate Partner	Director of Post-Graduate Planning, Franklin W. Olin College
Borovikova, Sophia [*she/her/hers*]	Student Researcher	Rising second year engineering major, Franklin W. Olin College

Stark, Stella [*she/her/hers*]	Student Researcher	Rising second year engineering major, Franklin W. Olin College
Kantor, Caitlin [*she/her/hers* | *them/them/theirs*]	Student Researcher	Rising third year engineering major, Franklin W. Olin College
Seitelman, Olivia [*she/her/hers*]	Student Researcher	Rising fourth year engineering major, Franklin W. Olin College
west, elizabeth [*she/her/hers*]	Site Host Partner Researcher	Permaculture practitioner and entrepreneur, Woodland Harvest Mountain Farm
Redman, Lisa [*she/her/hers*]	Site Host Partner Researcher	Permaculture practitioner and entrepreneur, Woodland Harvest Mountain Farm

Structure and foundation of case study

Establishing the research partnership derived from a trial period from August 2020 through May of 2021. During this period, west and Redman hosted a cohort of 12 undergraduate engineering students from Olin College, an arrangement that was initiated by Leon Santen, a rising senior and one of the students within the initial cohort. Of critical importance, Vanasupa and the site hosts began discussing the possibility of longer-term research around December 2020, with roughly monthly conversations prior to a site visit by Vanasupa and Phelps in May 2021. Many of the parameters for this case study were discovered through the trial period; the most essential of which was that all parties involved must choose the conditions, structure, and intent of the work.

The case study we report on here was a pilot, mutually-chosen by site hosts (west, Redman) and the principal researcher (Vanasupa) in May 2021, after establishing shared commitments and priorities: 1. safety (physical, emotional, psychological, social, academic); 2. community well-being 3. co-learning/equity 4. holism/health/healing. Prior to the case study, a Memorandum of Understanding was signed by the parties; it provided $5K in funds for on-site costs.

The learning experience ("the case study") took place from June through August, 2021, in the eastern United States. Vanasupa was responsible for creating the overarching structure of the 10-week experience which consisted of two main stages of action: 1. Four weeks of preliminary work in the northeastern region, with Franklin W. Olin College as the home base. 2. Six weeks of on-site research on the Woodland Harvest Mountain Farm (WHMF) in the Appalachian Mountains (west and Redman, site hosts) of North Carolina, which has a "primitive campground" designation. While technically considered a "front-country" site (i.e., within 30 minutes of a hospital), WHMF is not connected to: the electrical grid; municipal water or sewer; broadband internet or telephone. The hosts grow a variety of food and medicinal herbs and raise chickens, goats, ducks, pigs, rabbits and bees, among others. Electricity is available through a photovoltaic panel system (capacity < 2 kW) and a micro turbine powered by an on-site stream. The water source is the on-site stream; human sewage is handled through on-site composting toilets.

The student researchers were invited through an informed consent process. In it, they committed to working together prior to and on the WHMF site with the shared priorities and commitments to safety, community well-being, co-learning and holism, with Vanasupa as a remote guide. The project was conceived of as an exploration in engineering resilient living. Each student was paid a stipend ($5K), provided housing for the first stage (4 weeks with Olin as a home base) and charged $1K for room and board expenses for the second stage at WHMF, paid directly to WHMF.

Case study activities

Stage 1 began with capacity building and establishing a culture of safety. The first week, Vanasupa provided minimum curated content and questions regarding physical safety related to a primitive campsite. The research associates and Vanasupa met twice daily for dialogue related to their learning. The second week involved practices on embodiment of change using the text, "The Anatomy of Change" [5] . During this time, the research associates were also designing their activities for weeks three and four; work-day visits to regional sustainable farms. The research associates self-directed this portion of the work, autonomous researching and arranging their visits and associated travel. They also used the driving time to listen to audio books that expanded their understanding of sustainable farming. (e.g., “The Third Plate” [6]). The end of Stage 1 consisted of a road trip to the Stage 2 research site in North Carolina. This trip was disrupted, which will be discussed later.

Stage 2 involved living and working at WHMF. Their role was to be engineering partners to the hosts during the six weeks. It required that the student researchers take care of all their living needs (planning meals, cooking, cleaning). Because they had no transportation, the research associates spent all their time at the WHMF except for occasional trips to West Jefferson, North Carolina (an approximate 15-minute drive, one way) or outings related to the needs of WHMF. Host partners west and Redman served as learning guides and mentors. They identified project needs and shared knowledge, however they largely entrusted the research associates to design and complete the projects. These projects ranged in scale and scope from repairs (e.g., retrofitting a 200 square-foot building with shear bracing on the foundation) to designing processes (e.g., a humane process to harvest livestock). While there were several tools and materials at the project site, the associates most often worked within the design constraint of drawing only from the available resources on the property. Table 2 contains a partial list of the projects that were completed in the six-week period. During Stage 2, host partners Redman and west often worked with research associates and shared meals. The associates met with Vanasupa near the beginning via video call and spoke only twice to the associates via phone during the 6-week period at WHMF. At the completion of Stage 2, Vanasupa visited WHMF for two days, staying on-site in one of the primitive dwellings.

Table 2. Partial listing of projects completed at WHMF during Stage 2.

Retrofit a dwelling using shear bracing on foundation
Weather sealing a dwelling using cob and straw
Designing, building, and using tools from found objects
Protecting and local containment of livestock
Ergonomic redesign of food preparation space

Pesticide free infestation prevention
Soil water and nutrient retention
Safe transport of materials from high to low elevation
Design of efficient food storage pantry
Preserving fresh berries and fruits
Designing a humane harvesting process of livestock
Planning and implementing meal service for an event of 30 people
Daily care and feeding of selves
Insulating and water sealing structures with straw and cobb
Producing medicinal salves from herbs and plant oils

Findings

In reflecting on this particular group and the 6-week period, the host partners reported a very positive outcome, citing joy and a feeling of mutual respect that was distinct. Lisa Redman (host partner) on reflecting on the experience, "an emotion of joy and happiness came to me because that was definitely the overarching theme of the experience of the students' six week visit...". elizabeth west (host partner) in response to a typical day, "It was really joyful having them there,...so joyful, honestly, ...to get up in the morning and go see what people wanted to get into."

The site hosts reported that the research group earned their trust early in the Stage 2 work and there were no concerns nor incidents involving safety violations, which is not always the case. For context, prior to this case study, the host partners have hosted close to 3000 visitors at WHMF. The form that the hosting takes ranges from day trips to weeks-long. Visitors range in age and are often college-aged.

The primary experiences reported by student researchers were joy, holistic well-being, satisfaction in learning, awareness of connectedness to system, greater agency as an engineer, sense of engineering as sacred, adaptation, transformation in perspective, authentic collaboration. Below are examples of how these themes arose in the interviews.

Transformation

With the exception of the rising senior, the student research associates reported an experience of transformation. For some this meant they gained a different point of view and sense of self which was more capable than before.

> Sophia: "...definitely [an] experience that changed the way I look about things. It opened up my mind to how I think about working around problems or designing for different users or groups..."
>
> Caitlin: "...this felt transformational. I felt like I had gone there and gained a new perspective on things...I also gained a lot of confidence...which has actually been something that has translated the most in coming back to the real world...being able to carry myself with more confidence in my decisions."

Holistic Well-being/Joy

For the student researchers, this way of learning with well-being contrasted with their academic experiences, which leave them feeling as though they, as humans, are less valuable than their productivity.

> Caitlin: "…again, I love my school. I love Olin and I'm so proud of the work that I'm doing all of the time. But…once you …pause and reflect on the fact that …a ton of people are staying up until way past…when they should be asleep …I had [a] professor [who] really made it a point to…listen to [their] students… and understand that we are humans before we are students…even just that acknowledgement helps students feel more heard and know that there are more important things than learning and being a sponge, [otherwise we] push [ourselves]…to exhaustion that is in our day-to-day lives."

Several of the researchers described the cultural norm of on-going depletion in physiological, emotional, and mental well-being among the student population that comes from prioritizing productive academic output over human well-being.

The experience of being in nature and using their whole selves to learn and accomplish the work was rejuvenating in a way that is not experienced in a college learning setting.

> Sophia: "It was a very satisfying exhaustion. And being in that kind of setting, we were able to really renew our energy every day, because we were surrounded by nature and it was really revitalizing, and it made the work more satisfying…less …tedious and it made the work more positive… it wasn't like you had to sit in an office building looking at computer screens all day and looking at just very fluorescent lighting."

Upon reflecting about the research experience as a whole, Olivia remarked, "It was so lovely."

Greater Agency

Each reported a greater sense of their ability to do engineering or apply their knowledge. They felt empowered by their experience of having accomplished projects that were entrusted to them.

> Sophia: "...[it] was really gratifying, and it really showed the importance of what I can do and what kind of impact I could have, which more so fortifies why I chose the discipline that I did...it felt like I was making a visible impact in these peoples' lives...that was generally very rewarding."

> Stella: "I felt more empowered coming out of this experience...I feel more willing to try things that I've never done before, more willing to engage in spaces that I may not have before..."

Rejuvenating exhaustion

Several of the students talked about the work being exhausting but in a holistic way that was satisfying. They described the type of fatigue they experience as one which they could recover from through nightly rest and contrasted the experience with what is experienced in college.

> Sophia: “For example, at the end of the semester [at school],...we spend a lot of our time trying to ensure that we fit within...either grades or your personal commitment to how you want to do in school...it's very mentally exhausting rather than physically exhausting, whereas this summer, we did have to do a lot of problem solving, but we did a lot of physical work that was an application of those studies. So, it wasn't mentally draining in any way. It was more [that] you're tired after a hard day's of work. And it was very, ‘Yeah, I made an actual impact today and now I can rest easy, knowing that I've done my part.’ ”

> Caitlin: “At the end of every day, we were…physically exhausted, but it was…a sort of exhaustion where sleep could remedy that…a good meal could remedy that or spending time with friends could. Whereas, …all of us [at college] are more used to finishing days feeling completely mentally drained and exhausted, and sometimes sleep can remedy that, but sometimes we need more than just one night’s…good sleep…The student body is so constantly tired.”

When asked about the difference between the Woodland farm exhaustion and the college exhaustion, Caitlin referred to the college exhaustion as, “it’s almost [like]…a deflated balloon…I …physically feel like the sadness in my body and the weight of all the stress that I’m carrying…I don’t feel like that light happy person [I was at Woodland].”

Connectedness to self and to the world around them

They spoke of the value of being in a natural setting. Doing so was life-giving to them as well as educational in that they had a more acute sense of being part of the larger cycle of life.

> Olivia: "...existing in nature and also around animals...gave me a little bit more of an awareness of just the concept of life and that we were all alive and doing things [at Woodland]. You felt you were...actually existing and living in a different way than you can in brick buildings with pavement, because when you walk somewhere [at Woodland], you leave behind footprints. You have an impact on the space around you that you don't a lot here [at Olin]....it was just a different awareness of ourselves and our bodies and the space we took up and the impacts we could have...a more acute sense that you were part of the system you were living in."

> Stella: “...my perspective and my frame of reference has changed when it comes to thinking of consumption and thinking of how we're using our materials and resources here...I'm very curious now about conservation and the health of our ecosystems...now I feel like I can find that knowledge...to pursue that,...something that I would have never done before.”

> Sophia on working with the text on embodied change, “It made recognizing how my body works in different scenarios, it made me more cognizant of it.” The awareness for her enabled her to better understand how to efficiently, effectively and safely do things.

Collaboration

The student researchers reported having a deep experience of working as a team and authentically collaborating with the site hosts.

> Caitlin: “the [research] experience really helped us practice the ideas of engineering that are more...collaborating in that way [of] listening to the needs of their user....it really highlights being able to communicate with one another, being able to talk to Lisa and elizabeth and figure out what they actually need versus what we were just want to work on.”

They contrasted this experience with high-tech engineering college settings where there is a cultural hierarchy of what and who gets valued. Generally, the voices of those seen as having more expertise in technical content are weighted more heavily and, in some cases, the client's perspective, seen as “non-expert,” is de-valued or disregarded. At WHMF, they experienced authentic *collaboration*, which is a mode of working that involves shared power in decision-making . In school settings, they described experiences of *consultative* design (often called ‘collaborative’), where the expert holds the decision-making power. In consultative community-engaged learning, the designers' interests are often prioritized, leading to solutions that are not useful to the client, a common outcome of things like Engineers Without Borders projects [ref]. Additionally at college, the focus is on productive and time-constrained output, which often overrides any concern for well-being of the team or its members.

DISCUSSION

In considering the conditions that allowed these positive outcomes, it would be easy to confuse the form of this research with the substance. That is, one could get the impression that all that was required was a farm host site, four students, a couple of guides and 10 weeks in the summer. However, these features are superficial; we believe the deep structure of beliefs and values held by the participants were essential to the success of the experience. According to the cultural anthropologist E. Hall [7], these beliefs and values are the deep structures within a culture from which institutional structures are created. These structures condition systemic patterns of behavior that ultimately produce events, to include unintended consequences. These relationships are often mapped onto an iceberg to emphasize the idea that the deep structures are causal to the events; like a real iceberg, if one were to somehow destroy the tip, the structural dynamics (force of gravity, water molecule and ice structure) will interact to reproduce the tip. In the same way, the dynamics of a culture will reproduce the systemic outcomes if these structures are not addressed. The deepest (and most invisible) of these structures are the thought structures of beliefs and values.

For example, the site hosts, Elizabeth and Lisa, are seasoned in working with adult learners. They have practices that honor the dignity of adult learners and their autonomy. They communicate their needs without over prescribing the solution.

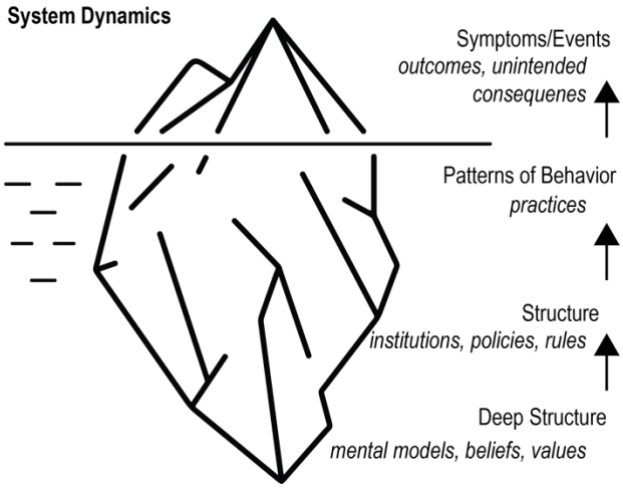

Figure 1. Iceberg model of system dynamics. This model was first described by E. T. Hall [7].

The effect of their way of working is that students have an opportunity to propose a solution and verify for themselves that it works; doing so leads to a sense of mastery.

> Stella: "Lisa and elizabeth were able to approach it...[in] a way that allowed us to find out for ourselves that we can do it..."

In college, where students' time and process is predetermined by an instructor, these conditions limit the learning:

> Sophia: "...the absence of this structure really enabled us to fully and deeply engage with whatever we were trying to work with or learn about."

So she was able to learn at the depth that she wanted and needed, the depth that was fit for the purpose without a time pressure. It also helped the group practice adaptation to the emerging weather conditions or other unexpected factors.

> Olivia: "...having the flexibility of not being super structured allowed for us to not struggle with changes in plans and situations we couldn't have predicted"

> Caitlin: "...a lot of what we learned came from things that were completely unplanned."

The deep structure--beliefs and values--of the research guides were codified in the shared priorities that they developed at the start of the case study: the primacy of holistic safety (physical, emotional, psychological, social, academic), community well-being, co-learning and

holism. Table 3 illustrates the deep structure within each of these priorities. By explicitly establishing these shared priorities, the collaborators' attention was focused and aligned.

Table 3. The deep structure within the research priorities for those creating the research arc (principal researcher, host partners).

Priorities	Values and beliefs
holistic safety	Ethic of care and safety (physical, emotional, psychological, social, academic) is the means of ensuring community health.
community well-being	Community well-being is the foundation for healthy outcomes. Productivity in the absence of well-being reifies white supremacy culture and is misaligned with the engineering ethics creed.
co-learning	Each of us can learn from the lived experiences and knowledge of others. We are all learners and all educators—learning is our natural state. All perspectives (*diversity*) are valuable and informative.
holism	Learning happens through the whole of our selves: mind, body, spirit. Nature is an essential partner to our existence as humans—we are part of the system that we desire to change. All of us are whole/healthy as a natural state—our inherited habits prevent us from experiencing our health/wholeness.

These values served as guides to make decisions. For example, Vanasupa chose a focus on creating an explicit *culture of safety* for the start of the Stage 1 work. This included research on food safety for primitive campsites and practices that raised awareness of safety. To promote the *culture of safety*, one or two individuals per day took on the role of safety facilitator. These individuals initially wore a neon orange safety vest as a visual reminder of safety they were creating together. However, when they reached WHMF, they discovered that a neon orange vest was more heavily associated with hunting for the hosts. Over the duration of the research, this *culture of safety* was internalized by the researchers such that each took accountability for one another's well-being, and they stopped using the vest. The internalized cultural values freed their attention so that they could be more present and therefore safer in their work together.

> Sophia: "Because we were all caring that each of us stayed safe,...we wanted to extend the safety towards the other members of the team so that we would not have to worry what we were working [on], about them being possibly unsafe, because that would sometimes disrupt the mental capacity to do work if we thought we were focusing more on making sure that somebody was being safe."

Olivia described a situation where the other three researchers sent her off to work on her creative things, "It's what I needed to be okay and what I needed for myself. And what I needed for myself was what the team needed." The team was freed from worrying about Olivia's well-being and therefore able to work more safely, knowing she was caring for her needs rather than forcing herself to work in a distracted mode.

Very importantly, the student researchers felt a sense of emotional and psychological safety in learning. Oftentimes classrooms have a quality of performance and judgment. The learning setting at WHMF felt more open and tolerant of the natural learning process, often chaotic and emergent.

Safety & community well-being

Equally important were the beliefs and values of the student research partners. They entered the work with a deep value for learning in a way that positively contributes to a sustainable future. Through an informed consent process where the priorities were explicitly stated, each entered the experience with agreeing to the priorities. With respect to community well-being each held a disposition of service to the site host partners of Stage 1 and Stage 2 research.

The prioritization of holistic safety manifest as an ethic of care for one another. The student researchers reported often thinking about safety and noticing when they were doing something that was potentially unsafe. This caused them to stop, name what was happening and take corrective action. A critical example of this was during their drive from the Stage 1 location to the Stage 2 location. They were traveling the approximately 400 miles by car. While on a highway, two of them sensed that the car was not functioning as expected and pulled over. They later discovered that the arm holding the front axle was detached from the chassis. If they had not been attentive to safety, they may not have noticed the subtle change in the car; their sensitivity prevented what could have been a catastrophic and potentially fatal car accident.

Student researchers also reflected on the sense of intellectual safety in the learning process that they felt from their hosts, west and Redman. For them, this was intellectual safety as defined by Schrader [8], “a caring environment in which the professor is open and caring, demonstrates respect, and embraces the uniqueness of students and their perspectives and does so in a classroom format where in which all are invited to participate actively, engage in personal self disclosure while trusting the confidentiality of such openness…” (p. 98). In the student researchers’ case, the hosts were a source of learning (i.e., “the professor” in the Schrader quote), yet they did not experience

Structure of co-learning and autonomy

The Stage 1 work enabled the student researchers to autonomously create a series of team trials where the errors were left at the trial site. In a sense, the physical act of moving to another site to learn enabled them to leave the feeling of errors at the site, but take the learning with them.

> Stella: "We were able to see how each other's brain worked in a way that had less consequence...what frustrates each other and what each others's strong suits were...So that when we came to the [Woodland] farm, we were ready to work as a team instead of still having to discover each other and see how that works as a team. And because we were moving, those little differences stayed with the place that we left."

> Olivia on the Stage 1 capacity building, "The most important thing that it taught us, so partly in just working together, getting to know each other, but also in the fact that...we worked as a team and [got to know] our different working styles"

In this way, the Stage 1 work served to create a team coherence that they could draw from in the Stage 2 work. Site partner west observed that the students arrived with a team coherence that normally takes time to develop on-site with other student groups.

The student researchers also felt empowered and a greater sense of agency because they were entrusted to choose our Stage 1 activities. They researched the locations that we wanted to visit and arranged the visits. Because they had to cold-call the sites and make our own travel plans, they experienced a sense of mastery and agency. Working on these sites were also of greater interest to us because we chose them; they felt more engaged with the work and obligated to our hosts because we made the commitments to the work visit ourselves. Had this work been pre-arranged by Vanasupa, they would not feel a sense of connection to the Stage 1 site hosts, nor would they feel the sense of having accomplished the visit ourselves.

These Stage 1 experiences also served to expand their understanding of what a sustainable farm could look like. Retrospectively, they reflected that the diversity of farms visited in Stage 1 opened their minds to possibilities and dispelled biases.

> Sophia: "...it definitely showed that this approach to sustainability can be very different and that should be embraced, ...especially how in nature, biodiversity leads to a healthier ecosystem and environment, a diversity of how you go about that will create a better ecosystem around the thought about farming like that...it doesn't just say, "This is how it must be done, and if you can't do it this way, you can't do it." It helped her to see that there is not just one right way, that there's a multiplicity of approaches.
>
> Stella: "All these farms were totally different...[working on them] helped get rid of all the biases that we had before coming in."

These experiences also dissolved for them what might have been a colonial dynamic where change agents who have no lived experience drop into the culture to “help” and leave. It enabled the researchers to acquire some experience prior to the Stage 2 work.

The value of the host partners (Stage 2, WHMF) as co-learners was also critically important to the positive experience of the hosts and the student researchers’ learning. For the hosts, they felt a sense of mutual respect that is not always present with visiting groups. For the student researchers, learning from the hosts was a rich experience, not only in the sense of content learning, but as authentic collaborative design.

> Sophia: "'...with a live person you can better address their overall needs by asking more questions and visually and intuitively seeing how they are reacting to it...it becomes actually collaborative instead of just being one-sided."

Holism with embodied practices

Being in nature had a healing and rejuvenating effect. This experience is underscored by the research findings of the value of natural settings for learning and creativity [8]. Paul documents the research findings indicating that such settings have a calming effect on the nervous system compared to the built environment. Students had just finished a year of remote learning, so being together as humans and moving through nature were powerful antidotes to being confined in the built environment. Many spoke of the value of moving their bodies and carrying for their whole human needs. The traditional college experience was described as one which causes them to be in one sitting position for hours, often ignoring their bodily needs because of the constant pressure for high productive output.

> Olivia: "...It was a big thing for me that we didn't ignore what we needed and how we were feeling because the classic thing [at college] is 'Oh, oops, I forgot to eat dinner. I was doing work.' That is so normal...[the needs of the body] are fully ignored. And the fact that we don't really get up and move that much...those are things that we all need."

In Stage 1, our study of "The Anatomy of Change" [5] allowed us to think of movement in our bodies as a way of learning and communicating.

> Stella:"[Practices on embodying change]...gave us a new language to discuss things,...so when we have conflict or someone was getting stressed, we were able to use that language...it broke down emotion into ways that we could feed together errand then work through it together."

Emergent findings show that our neurology stores past adverse experiences and that bodily movement is an aid to metabolizing negative experiences [9].

The disposition of holism enabled the student researchers to see engineering through a new lens. Being at WHMF enabled them to see that their engineering college culture held a narrow, high-tech definition of engineering; their experience on WHMF revealed that "everything that happens on a farm is engineering" (Stark). They valued the way of thinking that an engineering education provides, but felt misaligned with the embedded values of the engineering culture.

> Olivia: "I really like the way that I've learned to think here [at college], but I don't really like what I've done with it and what we were taught to do with it. ...I want to ...apply that way of thinking in more of a humanity, social justice space."

The student researchers realized that engineering is a way of applying knowledge and more successful when that knowledge serves the interests of the clients. The WHMF site itself had evidence where high-tech solutions were implemented by other visitors against the desires of the hosts and were no longer functioning—in essence these solutions were abandoned.

This research group adhered closely to the hosts' interests in all the projects they undertook. For example, the site hosts prefer to use materials that have a very small environmental footprint. Rather than purchase industrially-manufactured supplies, the student researchers used natural materials and found objects to achieve project goals. Doing so radically shifted student

researchers' perspective on their relationship to the natural environment and its value. For example, Stella reflected on harvesting animals for their food and the feelings arising from the intimacy with one's sacrificial benefactor,

> Stella:"We had to figure out a system to process all these hides and all these animals after,...we had to create these systems, but we were creating these systems that felt like they had more consequences...and there's so many emotions that I never felt [with inanimate projects]...thinking of the engineering process of something that is sacred...this is not something I can just ruin and it'll be okay...that [way of thinking] has translated into how I now feel about consumption...I feel more obligated to make the most [of materials we use]."

These transformational learning outcomes are aligned with the capacities needed for transdisciplinary design for sustainability. We believe that there are many incarnations of such learning experiences that can create the conditions that foster such emergent outcomes. Others can design incarnations for such transformational learning that draw on their situational resources. An important dimension of the experience was that the learning was situated in a sustainable context with a community of practice (i.e., the host family) versus abstracted. That is, the context of learning was a situation that was consistent with the desired outcomes. The difference between such a situated context and an abstracted one is like the difference between biological trials run *in vivo* (in the living organism) versus those run *in vitro* (in a petri dish). The living setting contains the whole, ourselves included as well as interconnections and nuanced dynamics that are unknown to us; the petri dish is a reduced environment that contains the things we imagine to be important. In other words, the living situation accounts for dynamic complexity whereas the petri dish design derives from a reductionist, simple-systems world view.

Reflection on missing element

Retrospectively, we note that "economic" safety was not explicitly named. This likely produced the result that during the after-action review, we realized the host partners were not sufficiently compensated for the holistic cost of the research. Olin college provided an additional $5K (U.S. Dollars) to WHMF after the completion of the case study to mitigate for this oversight.

Summary

This 10-week case study in situated learning resulted in rich outcomes that enhance the capacity for transdisciplinary design for sustainability: a holistic culture of safety, rejuvenating community and personal well-being, a social field of mutual trust and appreciation, collaboration with hosts/non-hierarchy in shared condition of living. The outcomes that arose did not do so in a predictable fashion. The principal researcher approached the case study with a disposition of emergence, believing that coherence in the deep structure across the collaboration would condition the outcomes. This deep structure involved a prioritization of holistic safety, community well-being, co-learning, and a disposition of holism. In essence, we created a situated research experience in which the means of learning (deep structure and situational factors) were consistent with the ends (the learning goals). We also note that in general, exposure to diversity

in all its forms has the potential to reveal and undo biases when people have a learning disposition. Those wishing to design such learning experiences may consider the following conditions that were present for this research: culture of safety (prioritizing well-ness), transformational intervention (psychosocial intervention that allowed autonomy and mastery), holistic focus (self-care, embodiment as learning, engineering as sacred, motion), natural setting (health, systems understanding), and situated learning (collaboration & teaming, required conflict resolution.)

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