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Engineering as Relational and Affective: High School Students Engineer for Their Community by Constructing a Community Garden

Yume Menghe Xu, Tufts Center for Engineering Education and Outreach

Yume is a PhD student in STEM Education at Tufts University. She holds a bachelor's and a master's degree in Chemical System Engineering from the University of Tokyo, Japan. Prior to pursuing a PhD at Tufts, she designed and developed educational apps for children, and worked with students, teachers, and makerspace in Japan to host making workshops using various materials and tools. Her research interest lies in youth's identity construction in STEM learning spaces.

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Abstract

With a growing emphasis on integrating social, political, and technical dimensions in K-12 and undergraduate engineering education, this research investigates how high school students learn and engage in sociopolitical engineering by constructing a community garden. Using a relational learning framework, the study examines students' experiences in a project called Ashford Youth Community Garden (AYCG), where students from a diverse urban high school collaborated with their peers, teachers, and community members to design and build a community garden in their schoolyard. Data was collected through interviews and focus groups with two students, Camila and David, who played leadership roles in the project. Findings reveal that students' emotional connections and relationships with the plants and their school community motivated sustained engagement and iterative design improvement, highlighting the importance of affect in engineering learning. The study suggests that facilitating engineering projects within students' own communities can foster meaningful sociopolitical engineering practices and promote deeper learning experiences. Additionally, it calls for the engineering education community to adopt relational and affective lenses in their research and practice.

Introduction

An increasing number of engineering curricula across K-12 and undergraduate levels is pushing for social, political, and technical integrations to steer away from the traditional engineering culture of solely privileging the technical dimension while downplaying the social and political dimensions [1]. Many of these curricula are discussion-based, where students have conversations about real-world engineering problems and how designs can impact the community [2]. In some cases, students work on design projects related to those conversations in their classrooms [3], [4]. While these contexts are certainly beneficial for students to become aware of and think about the sociopolitical aspects of engineering, it is also important for students to springboard from the classrooms and do engineering by engaging in real-world problems in the local community and working with community members.

Among the body of work around students engineering for real community needs, engineering education researchers study community engagement and provide examples of programs where engineering students did engineering work for communities [5], [6], [7]. These studies identified competencies that are important for engineering students to engage ethically with communities, such as being willing to listen to the communities, and transforming their assumptions and attitudes towards the communities. Moving forward, more research needs to be done on how to facilitate students to develop these competencies and how to support them in sociopolitical engineering. This study supplements the body of work by applying a learning sciences lens to better understand how students are learning in engineering activities for community engagement, and how I can better design these activities to support their learning. I looked into an engineering project where high school students constructed a community garden in their schoolyard in a course called "Engineering for our communities" as a case where students engineered through community engagement. I studied multiple interviews conducted with two students and analyzed how they narrated their learning throughout the project by asking a guided question, "What are the characteristics of students learning when they engineer a garden for their community?"

Literature review

Within engineering education research, scholars study community engagement (CE) as a way for students to do engineering for actual community needs. CE is often coupled with courses in undergraduate engineering programs (e.g. first-year project courses and senior design courses) where the students are tasked to create engineering designs for communities or individuals. Students usually communicate with the community members iteratively throughout the process to improve their design for the community's needs. Through CE, students learn to design within realistic constraints such as economic, environmental, social, and political. They also gain critical thinking, leadership, and communication skills, and understand professional ethical responsibilities as engineers [8]. CE can support students to learn and do engineering that incorporates the social and political aspects.

At the same time, research identified the challenges for CE pedagogies. In many cases, the students are tasked to work with under-developed communities they are not familiar with. Because of the lack of resources for students to immerse themselves in the community, and the lack of time to comprehensively understand the community's cultural, historical, and political contexts, students tend to make deficit-based assumptions about these communities when creating engineering design. Moreover, because these projects usually have a short timeline (e.g. within a semester) and are one-off, it is challenging for the students to consider how to sustain the projects with the community members in the long term [6], [7], [9]. These challenges can lead to harm to the communities and students not fully benefiting from the learning opportunities [5]. While previous research identified the challenges and provided visions for moving forward, research on how to better design CE activities to support student learning is still nascent. The engineering education field needs to share a theoretical understanding of what and how the students are learning engineering when they engage with communities to better design CE activities within the constraints of time and resources.

Calabrese Barton et al's study of middle school students creating engineering designs to address justice issues in their classroom shines a light on what and how students learn when engineering for communities. In the study, the students identified authentic problems (in opposition to problems prescribed to them based on the curricula), manifested their care for their community through creative engineering design that their teacher could not imagine, and came to see themselves as youth that can make positive change to their communities through engineering. The students' social interactions and relationships with people in their community supported what they designed, how their designs were taken up, and how their engineering learning unfolded [10].

Building upon Calabrese Barton and collaborators' work, I also focused on a project where the students engineered for their own community to study how the social interactions and relationships with the community supported students to learn and do engineering. During the process of constructing a community garden, the students in our study engaged with a large and complex system. Besides people in their class and their school, they also interacted with other members of the community such as the plants (the natural world), the residents, and the politicians of the city. Studying students' learning and doing engineering in a complex system can provide insights for designing CE programs that also involve diverse stakeholders and relationships.

Theoretical framework: Learning and doing engineering as relational

I adopt the perspective that learning is relational [11]. We live in a social world where learning happens through constant contact with others [12]. These "others" include people, the natural world [13], communities and cultures [14], [15], and physical and representational materials [16]. The relationships we form within a setting affect how we engage with learning in that setting. For example, in Nasir's work studying a high school basketball team, students as players developed relationships with their teammates and coach and felt valued because they could make a unique contribution to the team. They developed a sense of belonging [17] and were motivated to improve their basketball skills. A close relationship and a feeling of connectedness can motivate our engagement with learning. To learn in a discipline is not only to acquire knowledge and skills but to develop relationships with actors and communities related to the discipline.

In the recent movement to recognize engineering as not only a technical but a sociopolitical discipline, we can theorize that not only learning but doing engineering is relational. To name a few, when doing engineering, one forms relationships with materials and tools they use, people and communities who are collaborators and clients, and the natural world they learn from and work with to sustain [18], [19]. Along with the acquisition of engineering knowledge and skills, the development of these relationships is closely connected to one's learning and doing of engineering.

Additionally, I adopt an ecological view of learning to better understand the relationships connected to students learning and doing engineering [20], [21]. A learning activity is nested within different spheres of a person's overall ecology, including home, school, region, world, etc. The relationships one develops with these contexts all contribute to their way of learning and doing. Therefore, to understand students' learning, I look into the students' acquisition of knowledge and skills, along with the relationships they developed within the ecology when constructing Ashford Youth Community Garden (AYCG). Figure 1 is by no means comprehensive, but represents the various elements in the ecology of engineering learning and doing when the students constructed AYCG. For example, members in AYCG (plants, student members in AYCG, teacher members in AYCG, university partners) were who the students engaged with frequently when constructing the garden, and collaborated closely to make design decisions. Residents of Ashford City who live nearby frequently visited the garden and interacted with the students, and the students communicated with the elected officials in Ashford City for support and negotiations for the use of land.

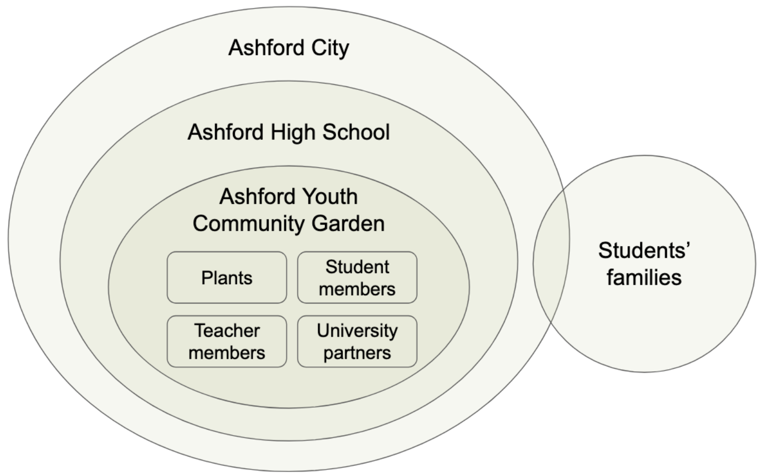

Figure 1. The various elements that constituted the ecology of engineering learning and doing when the students constructed AYCG.

Method

The project of focus: Ashford Youth Community Garden (AYCG)

AYCG stemmed from a long-standing partnership between a private university and a public high school in New England. The author of this paper is a doctoral student and research assistant in STEM education at the university. The high school is a large comprehensive urban high school that is racially, ethnically, and linguistically diverse. The partnership has been ongoing for over 20 years, with various collaborative efforts including transforming a dormant woodshop into a thriving makerspace in the high school and co-designing the high school's new engineering curriculum.

"Engineering for our community" is an engineering course offered by Ms. G at Ashford High School where students work with community members and create engineering projects for their school and the city's needs. In spring 2022, Ms. G worked with Ashford High School's environmental science teacher Ms. A, and researchers at the university to design the course for the students to construct a community garden in the schoolyard. Over the semester, the students worked in their makerspace to experiment with different types of hydroponic systems, design the outdoor garden space, reach out to the city and local gardening communities for support and advice, and start building raised garden beds. Students from Ms. A's environmental science classes also from time to time gathered in the makerspace to support the construction of the garden.

In the summer of 2022, the university funded a 6-week summer program where 13 students from the high school were hired to finish the construction of the garden. These 13 students were in either the engineering or the environmental science course that supported the garden construction during the spring semester. Together, the youth built 23 raised garden beds for over 20 species, with benches and signs to welcome visitors (Figure 2).


Figure 2. A glimpse of Ashford Youth Community Garden.

Data collection and analysis

I collected video recordings and fieldnotes during the summer, conducted focus groups with students before the start of the summer, individual interviews with the 2 teachers at the end of the summer program, and individual interviews with 13 students during and after the summer program. For this paper, I focused on 2 students, Camila and David, by analyzing the focus group and the individual interviews they participated in. Both Camila and David were rising seniors during the summer of 2022. Camila was in the environmental science class and David was in the "Engineering for our community" class. They both participated in the construction of the community garden from the start. I chose to study these two students because they presented as leader figures in the garden. Camila identifies as a Hispanic woman with White, African, and Indigenous identities. David identifies as an Asian American man.

Both the focus group and the interviews were semi-structured. Camila and David were in the same focus group with 3 other students. In both the focus group and the individual interviews, students were asked to recount their experience constructing the community garden through questions such as "What have been some of your favorite aspects of working in the garden?" and "Can you tell me about a time you felt frustrated in this work?" They were also asked about their aspirations for the future of the garden through questions such as "Where do you imagine the garden project going?" and "Let's imagine it's three years from now. What's happening in the garden? Who is involved? How does the community feel about it?" During the individual interviews, students were also asked about their relationship to STEM (e.g. How would you describe your relationship to STEM, and why?), and how did gardening impact their lives inside and outside of school.

I firstly coded Camila and David's focus group and interviews based on the acquisition of knowledge and skills and their relationships to the elements that constituted their learning ecology: plants, student members in AYCG, teacher members in AYCG, university partners, Ashford High School, Ashford City, and family (as represented in Figure 1). During the coding process, I frequently encountered affective expressions (e.g., proud, scary, relaxing, refreshing) related to the garden and the community. These expressions struck me because affective expressions are frequently avoided in the traditional engineering culture that values neutrality and objectivity. Therefore, I conducted a second round of coding to identify how Camila and David express affect when they talk about their developing relationships to better contextualize these developments. In this study, I present two of these relationships: to the plants, and to Ashford High School, and I provide an account of how they narrated their knowledge and skills acquisition alongside the development of these relationships.

Findings

Care and a sense of responsibility for the plants

Throughout the construction of the garden, students frequently talked about how much they cared about the well-being of the plants. For example, during the focus group before the summer program started, Camila answered the question "What are you most proud of about this work?" this way:

> *"What I'm most proud of is that the plants that were just in the corner or just by the back side wall of the makerspace have grown into full garden beds (...). And now they're growing berries or growing flowers. And I am very shocked because they were just so small. And of course, like what you (another student Diana) said, they're like my babies I feel like I watched them grow and grow into teenagers and then leave for college or something. [Laughing]"*

Over the semester, Camila witnessed the plants grow with her and other students' care. They started by creating hydroponic systems in the makerspace, planting the seeds, and monitoring the water and fertilizer in the system. Then they created the design for the outdoor garden, worked with the school for permission, communicated to the city for donations of soil, built their garden beds, and transplanted the seedlings from the hydroponics to the outside. The entire process made her feel strong emotional connections to the plants. Seeing the plants flowering and fruiting outside felt like seeing "babies" growing up and "leaving for college." As a rising senior, Camila was a teenager going through the process of college application and exploring her relationship with her family as she prepared to leave for college. Using a metaphor that overlapped with her personal experiences manifested the deep empathy and connection she felt for the plants.

Learning how to exercise her care for the plants contributed to her development of knowledge and skills. She started the spring semester as someone who grew up in an urban environment and never planted anything. Toward the end of the semester, she enthusiastically talked about the complex system involved in gardening and caring for plants that she learned over the semester:

> *"So gardening, when they think, when people think of gardening, they think of flowers, they think of easily just planting a… you know, a plant there and expecting it to grow, when really it's not the fact. You have to think of the nutrients that goes in the soil. Well, how much water it is for a plant, because the root systems might be different than another plant. Or they could end up bitter at the end, because there's too much water, like a*

cucumber, you know. The angles of which a plant is supposed to be, like the… the sweet potato that we learned yesterday as well. I didn't know that until then."

She learned about various elements that are involved in the ecology of plants, such as nutrients, water, and the physical setup. Through the experiences of caring for plants, she learned that different plants benefit from different configurations of these elements. She understood these as design constraints when building a garden to provide better care for the plants.

Her care for the plants also motivated her to think about how to design a sustainable future for the garden. When asked "What do you think the garden needs to be successful after the summer?" Camila answered,

"Having a strong layout of people or a group of people that are passionate about maintaining the garden, because I know people just join clubs because it looks good for college. But when you're dealing with actual plants, it's actual life that you're dealing with as well. So I can only hope that when we do have people that are willing to learn, willing to sit down and understand about certain things, then we will have a strong chance of keeping this club alive."

To sustain the garden, the students in the summer program decided to start a gardening club to continue taking care of the garden. Camila, David, and another student were voted to be the leaders of the club. As a leader, Camila prioritized a sense of responsibility for the plants when thinking about how to assemble a group of people for the club.

A deeper personal connection with Ashford High School

Students also frequently talked about how proud they were of the appearance of the garden and were excited to show the garden to people in the school. For example, David said this in the focus group after the spring semester:

"The part that I'm most proud about is probably being able to see all the physical stuff like the plants growing and the garden beds with all their paintings on it. Because it's like really good looking. (...) Anybody that walks past or like students at Malden High or to teachers, and like, every day when people walk past they're gonna see that big garden, they're gonna go, 'Wow, these kids are doing something. And this open space and they're taking advantage and they're helping out the community' and that makes me feel like better because then I'll be like -- when I'm older, I'll be like, 'Look, this garden? I kind of started.' You know?"

The students viewed the garden as something they started and constructed, and proudly called the garden "our garden." At the end of the spring semester, the students hosted a garden party where hundreds of students and teachers came to visit. I heard an overwhelming number of praises when people saw a gray part of the schoolyard turned into a beautiful garden with green thriving in it. Like David, the students who constructed the garden iteratively expressed joy when they showed their friends and teachers the garden they built. The garden seemed to play a role in deepening the AYCG student members' relationship with the school.

David and the other students came up with various design ideas to shape the garden into a learning and community space for the school. When David and several students were asked what they think the goal of the garden is, they said “to create an inviting space with opportunities for people to discover nature, learn gardening, and build community together.” To make the space more inviting, the students built a new bench and found several benches built by previous students in the makerspace and put them out in the garden so people could sit and spend time there. David initiated the construction of a three-tier garden bed that is taller than other beds so people who have back injuries do not have to bend or hurt their backs to care for the plants. To support people to learn how to garden, the students created an informational pamphlet about plant care, and planned to create signs with information and fun facts to be installed in the garden. Through the process, the students acquired knowledge and developed skills such as how to create sturdier wood structures and how to design and create a pamphlet digitally.

As a leader of the gardening club, David aspired to continue improving the design of the garden after the summer so people affiliated with the school could keep coming back to spend time in the garden:

> “*In three years, I think the community will like, like it (the garden) a lot, lot. (...) I think a lot of future students and their parents or like people that live around it will like keep on coming back to it over and over again, even like if they graduated or on holidays.”*

Discussion

Camila and David’s engineering work was deeply motivated by their affect and relationships with the plants and the school - elements in the learning ecology related to the garden. They continued to learn and experiment with better designs for the garden not because they were under academic pressure, but because they saw the work as beneficial for the community and could strengthen their relationship with the community. In Jaber and Hammer’s study in science education, they theorize that the affect one holds toward a disciplinary practice can lead to one's long-term stance toward engaging in the discipline. In other words, when a student experiences emotions such as excitement when exploring science problems, they may feel more inclined to do more science in the long run [22]. In Camila and David's case, their affect and sense of care towards the plants and the school motivated them to iteratively improve their engineering design. Because of their affect and engagement, the plants and the school provided them with positive feedback by thriving and approving their work. The positive feedback in turn motivated their further engineering learning and doing. The feedback circle sustained by relationships supported Camila and David’s deep engagement in engineering for their community.

Relationships and affect can be an important lens to understand students’ learning when they engineer for communities. Conversations around affect, feelings, relationships, and interactions are historically marginalized in engineering because engineering is portrayed to be objective and neutral [18], [23]. Emotions were often associated with female characteristics and were discriminated against by the historically masculine engineering culture [24]. However, I see from this study that relationship and affect are essential components that motivate students’ engagement with engineering learning and doing. This suggests that when designing CE engineering activities, we should strive to design a learning ecology that supports students to hold affect and develop relationships through their engineering work.

Many CE projects studied in previous research require students to work on projects for other communities that they are not familiar with. While a setup like those can help students to learn about the social and historical context and become empathetic of other cultures, it takes time and resources to fully immerse the students in those cultures to reach an adequate understanding. In the work of DeBoer and colleagues [25], they describe an international development program where scholars in the United States designed for out-of-school youth and refugee students to engineer solutions for their own communities. By supporting the youth to engineer for their own community, the youth created long-lasting solutions and became more connected to engineering as a discipline. This study echoes with DeBoer and colleagues' findings on the merits of having youth engineer for their *own* community. The students are more familiar with the context of their community to begin with, so it is easier for them to develop affect and relationships with the community. It will also serve as a great opportunity for the students to be more connected with their community. Perhaps the process of developing affect and relationships through engineering for their own community can support students to be more empathetic when they move on to engineering for other communities later on.

Although gardening is not traditionally perceived as an engineering activity, AYCG showed us that gardening can be an engineering-rich activity that supports students to learn and do community-based engineering. ABET defines "engineering design" as "a process of devising a system, component, or process to meet desired needs and specifications within constraints. It is an iterative, creative, decision-making process in which the basic sciences, mathematics, and engineering sciences are applied to convert resources into solutions" [26]. Students at Ashford High School went through the process of engineering design when they constructed and took care of the community garden. They identified the constraints such as plants' desired living conditions, materials and budget they had, and the condition of the land they were allowed to use in the schoolyard. They built the garden and iteratively improved the design by making decisions using their science, mathematics, and engineering knowledge. The garden was a platform for the students to develop relationships and exercise their care for the community through engineering. I would like to suggest that gardening can be a potential venue for students to engineer for their own communities.

Conclusions and implications

By studying high school students constructing a community garden as a project sprung from their engineering course, I theorize that relationships and affect can support students to better engage in engineering learning and doing. Although not frequently come up in conversations around engineering or engineering education, relationship and affect can be a powerful lens to study students' learning when they engineer for community engagement. Situating an engineering project in the students' own community can better support students to develop relationships and affect with the community within limited time and resources, so they can better learn and do sociopolitical engineering. For future work, I plan to study how other elements in the learning ecology (e.g., Ashford city, students' families) impact students to do and learn engineering. Besides their acquisition of knowledge and skills, I would also like to study how the relationships and affect impacted the students' identity development and how they see themselves related to engineering in the long term.

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