2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #37850

Board 174: Stakeholder Views in Building a Sustainable Engineering Learning Ecosystem: Afterschool Green Energy, Robotics, and Automation (Work in Progress)

Allison Antink-Meyer, Illinois State University

Allison Antink-Meyer is a professor and pre-college science and engineering educator at Illinois State University.

Dr. Matthew Aldeman, Illinois State University

Matthew Aldeman is an Associate Professor of Technology at Illinois State University, where he teaches in the Sustainable & Renewable Energy and Engineering Technology undergraduate programs. Matt joined the Technology department faculty after working at

Dr. Jin Ho Jo

Dr. Jin Jo is a Professor of Technology at Illinois State University, teaching in the Sustainable and Renewable Energy program. Dr. Jo also leads the Sustainable Energy Consortium at the university. Dr. Jo is an honors graduate of Purdue University, where he earned a B.S. in Building Construction Management. He earned his M.S. in Urban Planning from Columbia University, where he investigated critical environmental justice issues in New York City. His 2010 Ph.D. from Arizona State University was the nation's first in sustainability. His research, which has been widely published, focuses on renewable energy systems and sustainable building strategies to reduce the negative impacts of urbanization.

Jeritt Williams, Illinois State University

Jeritt Williams is an assistant professor of Engineering Technology at Illinois State University, where he teaches applied industrial automation and robotics.

Maria Luisa Zamudio

Stakeholder Views in Building a Sustainable Engineering Learning Ecosystem: Afterschool Green Energy, Robotics, and Automation

(Work in Progress)

Abstract

This research was part of the first year of a National Science Foundation funded project aimed at promoting high school students' interest in green energy, robotics, automation and post-secondary engineering and technology study. High school teachers, undergraduate majors in STEM areas, and community based non-profit organizations were involved in this afterschool engineering program for high school students with the goal of broadening participation among minoritized groups in engineering and engineering technology. This study investigated how these different stakeholders' views aligned and diverged about (1) the characteristics of STEM engagement, and (2) the factors that influence the development of engineering identities. The purpose of this investigation was to uncover the relationships between community members' viewpoints, community assets, and the positionality of the project personnel.

Introduction

SUPERCHARGE is an NSF ITEST funded project designed to engage high school students in four Chicago communities in an afterschool program focused on the design of technologies to promote green energy in their communities. At the time of this work-in-progress study, three years of activities were being developed by the authors who are university faculty and a team of undergraduate majors in STEM fields. Each year incorporates micro:bit computers and Microsoft MakeCode across two units of four modules of activities. These eight modules are developed to engage high school students, who may have little hands-on engineering design experience, with learning skills and technologies that they then apply to a culminating engineering design challenge each year (see Aldeman et al., 2023 ASEE paper for more detailed program information). Each design challenge relates to a local problem and the module activities are designed to scaffold student learning about local green energy initiatives, technologies that enable them to collect data, and guided design activities that help them learn how they can contribute. The design challenge in the first year is a weather station that can be used to gather information about air quality, ozone action days, precipitation, wind, etc. The second year culminates in a solar photovoltaic robotic tracking system, and the third year culminates in the design and testing of an all-terrain electric scooter.

In addition to the faculty and students who are developing the modules, each of the four communities consist of a partnership group of stakeholders. These groups include the university, a high school and teachers who will implement the activities in the afterschool program, and a community-based organization. Each group of teachers provided feedback on the activities as they were being developed. Each community-based organization provided local contacts and connections to how environmental challenges were affecting the community and what STEM projects and initiatives existed locally that could tie into the SUPERCHARGE activities. These included connections to air quality monitoring station data collection programs, solar arrays on local community centers, closed loop zero waste facilities with digesters, and community gardens.

The teachers, undergraduate STEM majors, and community-based organizations each brought unique perspectives to the creation of the afterschool activities. This study is in its early phases and will continue across all four years of the project. The contribution it can make to the literature at this time is to illuminate the extent to which stakeholders who have a shared goal might also have unique perspectives on STEM engagement and the factors that influence the development of engineering identities. Understanding the differences in perspectives can support dialogue across groups.

Theoretical Framework

Cheville [1] described "an increasing inequity in the K-12 system with the growing re-segregation of schools. [This] poses a threat to engineering education efforts focused on diversity, access, and inclusion" (p.7). The afterschool program that was the focus of this study was designed using a STEM Learning Ecosystem model, which centers on the student [2][3] [4]. The model was selected to inform the development of a program that would acknowledge sociohistorical underpinnings by leveraging local cultural and academic assets. The purpose of this focus was to not frame the schools, learners, and partners through a deficit lens. The model identifies direct (e.g. home, school, neighborhood), indirect (e.g. workplaces, school boards, geographies), and broad cultural (e.g. histories, customs, government) influences whose relationships with one another and with individuals illuminate the contextualized nature of STEM learning. Promoting access and inclusion to STEM among adolescents attending resegregated schools in predominately Black and Latinx communities in a large city in the U.S. is the mission of SUPERCHARGE. Hecht and Crowley [5] argue that "learning ecosystems requires moving away from thinking of the ecosystem as a complicated set of interconnected pieces and toward thinking of the ecosystem as *a complex* with elements that exist through their relationship with each other" (p. 5). SUPERCHARGE was designed to position itself within an ecosystem without a center [5], where curriculum, community, and partners interact with one another and where those interactions contribute to student identity building in STEM through engaging and meaningful engineering experiences.

This model influenced the program and research by (1) focusing on, and utilizing, the assets that exist in communities through collaboration with teachers, schools, and community-based organizations and, (2) creating pathways of access to information about green technologies, post-secondary educational opportunities, and STEM careers. The STEM Learning Ecosystem model [2] makes the "dynamic interaction among individual learners, diverse settings where learning occurs, and the community and culture in which they are embedded" (p. 5) explicit. That interaction, however, does not imply universal coherence among the views, assumptions, and priorities of all stakeholders. During the design of the afterschool curriculum, the authors interviewed the high school teachers who would be implementing the program, the undergraduate students who were creating and piloting activities, and the education directors in community-based organizations who were partners on the project. The research question that guided this work was

How do undergraduate students', afterschool teachers', and community-based organizations' view meaningful STEM engagement and the development of engineering identities?

Meaningful STEM engagement

STEM engagement describes the interaction of learners with learning materials that integrate the practices and concepts of science, technology, engineering, and mathematics. While each STEM area comprises its own way of knowing, we viewed engineering as the underlying driver of STEM engagement in SUPERCHARGE and as the motivation for the integration of the other domains as well as for the skills and knowledge associated with those domains. Thus, we used the characteristics of engagement were comprised by Cunningham and Kelly's (2017) epistemic practices of engineering in this study because they are reflective of the nature of engineering, specific to the habits of mind reflected in the Framework for P12 Engineering Learning, but general enough to be more likely to arise in the interviews. The three groups of stakeholders whose views were examined in this study are not engineers and it was unlikely that their reflections on STEM engagement would be specific enough for the Framework (2020) to be the most meaningful descriptors of their views. For example, it was unlikely that the community-based organization participants would make an explicit reference to the engineering practices of fabrication or engineering graphics. The epistemic practices of engineering used were :1) developing processes to solve problems, 2) considering problems in context, 3) envisioning multiple solutions, 4) innovating processes, methods, and designs, 5) making trade-offs between criteria and constraints, 6) using systems thinking, 7) applying math knowledge to problem-solving, 8) applying science knowledge to problem-solving, 9) investigating properties and uses of materials, 10) constructing models and prototypes, 11) making evidence-based decisions, 12) persisting and learning from failure, 13) assessing implications of solutions, 14) working effectively in teams, 15) communicating effectively, and 16) seeing themselves as engineers. In the SUPERCHARGE afterschool program, engagement in these epistemic practices was framed by weekly activities that developed skills and conceptual competencies. These were developed so that halfway through an academic year a related engineering design challenge would be introduced, and the remainder of the year would focus on student engagement in an iterative engineering design process including prototyping, testing, and optimization.

Engineering identities

Identity development is often framed through a sociocultural lens which describes identity as multidimensional, interactional, and embedded in how an individual understands their cultural past, present, and future [6]. We defined engineering identity as a socio-culturally and personally constructed view of yourself as an individual who can do engineering design and who feels a sense of belonging within engineering. This definition is an adaptation of the PEAR Institute and the sociocultural perspectives reviewed by Verhoeven and colleagues. Future studies of SUPERCHARGE will utilize the Common Instrument for students and educators from the PEAR Institute [7]. The STEM Learning Ecosystem model was used as a lens to explore the factors of influence in engineering and STEM identity development in this study.

Methodology

Participants

This study is a work in progress and at this time the participants included four undergraduate students who were working as curriculum designers (henceforth Designers), five high school teachers who would supervise the afterschool program in the following school year, and three education coordinators from the partner community-based organizations. The Designers were undergraduate majors in Renewable Energy, Engineering Technology, or Special Education (one student) programs. They worked closely with the authors to develop activities using the micro:bit around phenomena and technologies relevant to climate and weather. Two of the students identified as female and two as male. They were between their sophomore and senior years. Each Designer spoke English as their first language.

The high school teachers taught Computer Science, Biology, Anatomy and AP Environmental Science and their teaching experience ranged from six to 18 years. The SUPERCHARGE activities developed by the authors and Designers were also shared with the teachers for feedback during program development. At the time of this study, they had not yet received any activities to review.

Interviews

The data set analyzed in this study consisted of semi-structured, open-ended interviews with a sample from each stakeholder group (two teachers, two community-based organizations, and four undergraduate student designers). Each interview took 45 minutes to an hour. Participants were asked about their prior STEM experiences and interests, their perspectives on the SUPERCHARGE curriculum and mission, and their perspectives on how best to integrate SUPERCHARGE activities within the communities and schools in each of the four program sites. The interview questions are shown in Table 1. All interviews were conducted in Zoom and transcribed by the program. Author 1 cleaned the transcripts using the recorded interviews.

Table 1

Semi-structured, open ended interview questions

Teachers	Community Based Organizations	Undergraduate Students
(1) How long have you been teaching and what subjects/classes have you taught? (2) What childhood experiences influenced your interest in STEM/science? In teaching? How did your family affect your interest? Friends? Teachers? (3) What educational experiences influenced your interest in a STEM teaching? How did your school environment affect your interest? After-school and summer experiences? Museums or other experiences?	(1) Please tell me about your CBO. How does your organization affect the high school students and families in the community? The businesses? Cultural institutions? (2) What other STEM-related programming is your organization involved in? What influences your decision about what programming to pursue? (3) SUPERCHARGE programming engages high school students with learning about sustainability technologies including robotics and	(1) What childhood experiences influenced your interest in a STEM major? How did your family affect your interest? Friends? Teachers? (2) What educational experiences influenced your interest in a STEM major? How did your school environment affect your interest? After-school and summer experiences? Museums or other experiences? (3) What are some examples of things you have learned in your major? What are some examples of how you have learned in your major? Does the way

(4) What are some examples of things you have learned about the community in which you teach? How does that understanding influence your teaching? What are some examples of how high school students learn STEM in your school? Does the way they learn STEM affect what they learn? (5) SUPERCHARGE programming engages high school students with learning about sustainability technologies including robotics and green energy applications. The culminating project for the coming year is (Year 2: Smart Weather Station; Year 3: Solar Photovoltaic Robotic Tracking System; Year 4: All-Terrain Electric Scooter), how does this project relate to the STEM classes they may have taken already? Does the project relate to your teaching experiences? (6) What do you think affects the disparity in attainment of STEM degrees among college students of minoritized groups? (7) How do you think local STEM related businesses, museums or other cultural centers, library programs, schools, influence high school students' interest in STEM? (8) What do you think helps high school students shift from having an interest in STEM to thinking of themselves as a STEM major? (9) How effective do you think SUPERCHARGE activities will be in helping foster high school students' interest in STEM? What about their identity as STEM people? (10) Is there anything wish you knew about the undergraduate STEM majors and ISU faculty who are creating SUPERCHARGE programming? What do you wish they knew about you? What do you wish they knew about the high school students? What do you wish they knew about the community? Why are those things important to the SUPERCHARGE curriculum?	green energy applications. The culminating project for the coming year is (Year 2: Smart Weather Station; Year 3: Solar Photovoltaic Robotic Tracking System; Year 4: All-Terrain Electric Scooter), how does this project relate to the institutions and businesses in your community? (4) This is a table (show NCSES Table below) that illustrates the percentages of STEM college degrees awarded in 2019. The other table shows the racial breakdown of the US population in 2019 in case that helps you think through the numbers. What do you think affects the disparity in attainment of STEM degrees among college students of minoritized groups? (5) How do you think local STEM related businesses, museums or other cultural centers, library programs, schools, influence high school students' interest in STEM? (6) How effective do you think SUPERCHARGE activities will be in helping foster high school students' interest in STEM? What about their identity as STEM people? What advice would you offer ISU and teachers about how to embed community assets within programming? (7) What do you wish you knew about the undergraduate STEM majors and ISU faculty who are creating SUPERCHARGE programming? What do you wish they knew about your community? What do you wish they knew about the high school students? What do you wish they knew about the local institutions? Why are those things important to the creation of SUPERCHARGE curriculum?	you have learned affect what you have learned? (4) SUPERCHARGE programming engages high school students with learning about sustainability technologies including robotics and green energy applications. The culminating project for the coming year is (Year 2: Smart Weather Station; Year 3: Solar Photovoltaic Robotic Tracking System; Year 4: All-Terrain Electric Scooter), how does this project relate to your major or your interest in STEM? (5) This is a table (show NCSES Table below) that illustrates the percentages of STEM college degrees awarded in 2019. The other table shows the racial breakdown of the US population in 2019 in case that helps you think through the numbers. What do you think affects the disparity in attainment of STEM degrees among college students of minoritized groups? (6) How do you think STEM related businesses, museums or other cultural centers, library programs, schools, influence high school students' interest in STEM? (7) What do you think helped you shift from having an interest in STEM to thinking of yourself as a technologist, engineer, scientist…? (8) How effective do you think SUPERCHARGE activities will be in helping foster high school students' interest in STEM? What about their identity as STEM people? (9) What do you wish you knew about the high school students who are engaging with SUPERCHARGE programming? What do you wish they knew about you? What do you wish you knew about the teachers who are leading the program? What do you wish you knew about the community? Why are those things important to your creation of SUPERCHARGE curriculum?

Analysis

The authors used provisional coding [8] as a first cycle coding method [9] based on the epistemic practices of engineering and the four levels of the STEM Learning Ecosystem model (broader cultural influences, contexts influencing a child indirectly, interconnections among contexts, and direct interactions of child and context) to analyze the interview transcripts. Pattern coding [8] will be used as a second cycle coding method as the study develops in order to describe the networks and patterns that emerged in interviews within each group of stakeholders, but also to establish the foundation for future cross-case analysis [9].

Findings

The research question, *how do undergraduate students', afterschool teachers', and community-based organizations' view meaningful STEM engagement and the development of engineering identities*, was examined by looking for segments in transcripts where codes for the epistemic practices of engineering (used to operationalize meaningful STEM engagement) and codes for the STEM learning ecosystem (used to operationalize the factors that influence engineering identities) co-occurred.

The provisional codes were generated in Dedoose [10] and each group of stakeholders was analyzed for predominant co-occurrence of codes. To inform the research question, predominant co-occurring codes from each group were compared. *Predominance* was defined by examining the highest frequency of each code within stakeholder groups and across stakeholder groups. Tables 2 and 3 illustrate the frequency of all codes. An example of code application of the epistemic practice *seeing themselves as engineers,* for example, was the statement from one teacher that

> There'll be people working in the field who will, you know, via zoom, they'll present to your class, and they talk about what they do. So then that's another way to expose students to what they could do. They don't go into it, because they're not believing in themselves. And then there's then there's a stereotype of them, and then resources are limited for them.

Table 2

Meaningful STEM Engagement (Epistemic Practices of Engineering)

	applying math know-ledge to problem-solving	applying science knowledge to problem-solving	communi-cating effectively	considering problems in context	innovating processes methods, and designs	making evidence-based decisions	constructing models and prototypes	persisting and learning from failure	seeing themselves as engineers	using systems thinking
C1	0	0	0	3	0	1	0	0	3	0
TA1	0	0	0	0	1	0	2	3	7	0
TB2	0	0	1	0	2	0	1	1	7	0

C3	0	0	0	0	0	1	1	0	0	0
Undergrad	1	0	0	1	0	0	2	0	1	1
Undergrad	1	2	0	2	1	0	0	1	9	2
Undergrad	1	1	0	1	0	0	0	0	2	1
Undergrad	0	0	0	1	1	0	0	0	4	0

(C: community-based organization; T: teacher; number indicates the community of association)

Table 3

Engineering identities: STEM Learning Ecosystems

	Reflection on non-program contexts	Reflection on program	Reflection on self	interconnections among contexts	broader cultural influences	contexts influencing a child indirectly	direct interactions of child and context
C1	2	6	0	3	4	4	4
TA1	8	2	3	3	2	2	4
TB2	7	2	1	7	1	1	2
C3	3	1	0	1	1	0	3
Undergrad	0	4	4	3	0	3	2
Undergrad	1	5	7	1	3	4	9
Undergrad	2	2	6	1	1	3	6
Undergrad	0	5	2	1	2	3	3

Table 4 identifies the most often co-occuring codes between what views participants expressed around what makes STEM engagement meaningful and what supports the development of an engineering identity. The most common epistemic practice of engineering coded that reflected all three groups of stakeholders' views about meaningful STEM engagement was students *seeing themselves as engineers.* An example from a teacher in community 1, teacher TA1, illustrates the most common co-occurrence of codes where *seeing themselves as engineers* and *interconnections among contexts* were applied.

> With exploring computer science again, skills that I feel like for them because there are all my students are minority. It's like I'm showing them, and everything is like, you know, the curriculum didn't plan so well that it's accessible to the students, and so they see that they can do it. So like when we are building web pages, and they're seeing that they can do it. "Oh, this is cool when we're programming". So then they get excited because they feel like now they're into learning. Now, there's a skill that they can do. And even when they like, oh, we're doing web pages like a lot. I have like low-level students. And so when they're writing, it's a struggle. But I tell them, just give me whatever you want to write I don't worry about spelling. Don't worry about how you're saying it. Looking at your code, I'm on necessary looking at your writing, I will be able to figure out your ideas I'm looking at your code and they buy into it. So it is been like, I'll have other colleagues come and say, Hey, they're passing your class, and they're actually doing very well, but

they don't do so well in my class. I'm like you try to explain to them. It's kinda like they're liking it because they can do it.

Table 4

Most common co-occurrences of provisional codes [8]

	Participant	**Meaningful STEM Engagement (Epistemic Practices of Engineering)**	**Influences on Engineering Identities (STEM Learning Ecosystem Model)**
Teachers	Teacher A1; Teacher C2 (6 co-occurrences)	Seeing themselves as engineers	Interconnections among contexts
	Teacher A1; Teacher C2 (4 co-occurrences)	Seeing themselves as engineers	Direct influences on the child
	Teacher A1; Teacher C2(3 co-occurrences)	Persisting and learning from failure	Interconnections among contexts
	Teacher A1; Teacher C2(3 co-occurrences)	Innovating processes, methods, and designs	Interconnections among contexts
Community Based Organizations	Communities 1 & 2 (3 co-occurrences)	Seeing themselves as engineers	Broader cultural influences
	Communities 1 & 2 (2 co-occurrences)	Seeing themselves as engineers	Direct influences on the child
Undergraduate Designers	All Undergraduates (9 co-occurrences)	Seeing themselves as engineers	Direct influences on the child
	All Undergraduates (5 co-occurrences)	Seeing themselves as engineers	Contexts influencing a child indirectly
	3 Undergraduates (4 co-occurrences)	Seeing themselves as engineers	Broader cultural influences
	3 Undergraduates (3 co-occurrences)	Considering problems in context	Broader cultural influences

Early analyses revealed both points of common views as well as diverging perspectives. Common purposes across stakeholder groups were exclusively focused on students seeing themselves as engineers and accessing career pathways. Views about what, and how, to support the development of STEM identities, however, suggest that their positionality influenced their perceptions and priorities, and these varied across the groups in their preponderance (see Table 4). The epistemic practice of engineering that was most prominent in the interviews across all three groups was students *seeing themselves as engineers.* The only influence on the development of an engineering identity that was described by each stakeholder in the same utterance (utterance; defined in this study as a segment of transcript expressing a standalone idea) was focused on *direct influences on the child*. Direct influences are factors like family and teachers who have direct interactions influencing a child's experiences and perspectives.

Conclusions and Future Work

The influences on the development of engineering identities [2] were points of divergence across the stakeholder groups. As additional interviews are completed and analyzed across the four years of the program, we are interested to learn more about whether perspectives begin to converge. Or as more epistemic practices arise, do stakeholders perspectives about what contributes to the development of engineering identities shift in new ways?

References

[1] R.A. Cheville, "Board # 22 : Ecosystems as Analogies for Engineering Education," in *ASEE Annual Conference & Exposition*, 2017.

[2] National Research Council (NRC), *Identifying and supporting productive STEM programs in out-of-school settings.* Washington, DC: National Academies Press, 2015.

[3] B. Barron, Interest and self-sustained learning as catalyst of development: A learning ecologies perspective. *Human Development*, 49, pp. 193-224, 2006.

[4] K. Wade-Jaimes, K. Ayers, and R.A. Pennella. "Identity across the STEM ecosystem: Perspectives of youth, informal educators, and classroom teachers." *Journal of Research in Science Teaching* (2022).

[5] M. Hecht, and K. Crowley. "Unpacking the learning ecosystems framework: Lessons from the adaptive management of biological ecosystems." *Journal of the Learning Sciences* 29(2) (2020): 264-284.

[6] M. Verhoeven, AMG Poorthuis, and M. Volman. "The role of school in adolescents' identity development. A literature review." *Educational Psychology Review* ,31, pp. 35-63, 2019.

[7] The PEAR Institute. Assessment tools in informal science Boston, MA: Program in Education, Afterschool, and Resiliency; Harvard University; and McLean Hospital. http://pearweb.org/atis. 2018.

[8] M.B. Miles, A.M. Huberman, J. Saldaña. *Qualitative data analysis: A methods sourcebook* (4th Ed). Sage. (2020).

[9] J. Saldaña. "The coding manual for qualitative researchers." *The coding manual for qualitative researchers* (2021): 1-440.

[10] Dedoose Version ***9.0.17***, web application for managing, analyzing, and presenting qualitative and mixed method research data ***(2021)***. Los Angeles, CA: SocioCultural Research Consultants, LLC www.dedoose.com.